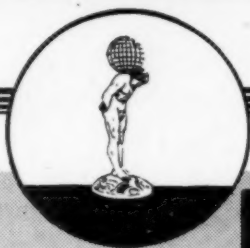


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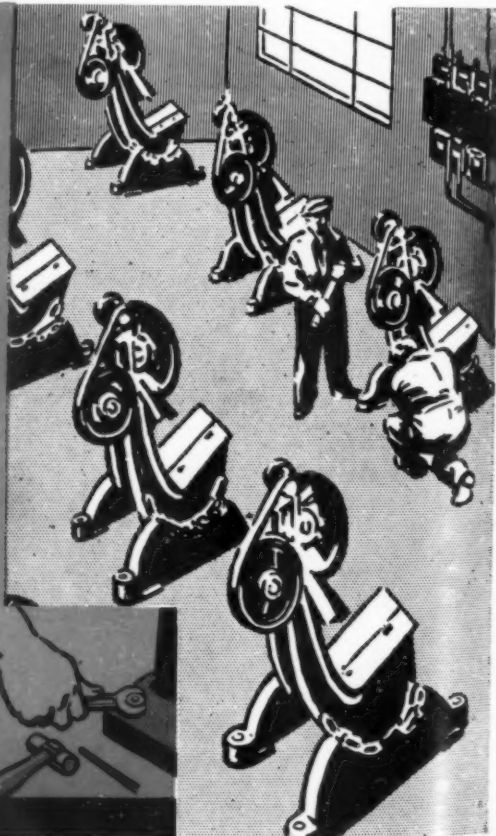
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# METALLURGIA

## *The British Journal of Metals*

(INCORPORATING THE METALLURGICAL ENGINEER)

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# METALLURGIA

THE BRITISH JOURNAL OF METALS.

INCORPORATING "THE METALLURGICAL ENGINEER."

JULY, 1944

VOL. XXX. No. 177

## Efficiency in Production British Industry's Post-War Need

**D**URING the progress of a war, particularly one of such dimensions as is being waged now, the demands of the peoples at war become increasingly persistent with the trials they are called upon to bear. All the main problems encountered in peace times are emphasised and advantages are demanded which, unless carefully considered, will tend to undermine the whole economic structure of the countries concerned. In Britain, for instance, as Sir George Schuster points out in *The Times*, there are persistent demands for more wages and less hours; family allowances, higher old age pensions and unemployment benefits; housing and replanning programmes; raising of school ages and retarded entry of boys and girls into employment; more armaments; possible agricultural subsidies; more exports to pay for imports formerly bought with revenue from overseas investments.

These are the most important of what can be regarded as very proper demands. Few will take exception to any one of them. But, while the propagandists for each of them are many and are convincing, only relatively few indications have been given as to how these demands are to be satisfied. It is only by increased work that these advantages can be achieved, and increased work can only be obtained when the products are competitive in price and quality. Thus, the primary concern of British industry should be efficiency in production and service.

The suggestion has been made from time to time that by the careful use of the British import market as a means of bargaining, it should be possible to expand exports to the level required to meet the cost of imports. Under certain conditions political influences may be used to effect such an exchange, but care must be exercised to guard against political manipulation of markets to force products on other countries. The aim should be to build up sound markets for British products by making the products competitive in price and quality and the advantages that accrue from good service should not be overlooked.

The expression "increased efficiency of production" is frequently used without discrimination. In its broadest sense it not only includes developments resulting from scientific and technical research, and the use of the most modern plant and machinery, but also the human factors involved in industry. The relations between workers and managements and the attitude of the workers to their jobs present problems that in

many respects are as complex as the technical and scientific problems of industry—indeed, it is probable that they are more urgent of solution. Obviously, as soon as workers and managements unite in service with the common object of using the most up-to-date machinery available to reach the highest possible degree of efficiency, the demands of the community are more likely to be met.

It has been suggested that the period of transition from war- to peace-time activities will be most critical immediately on the termination of hostilities in Europe, even though the war may continue in Asia, that while the production of munitions will go on, it will be at a substantially reduced level. The view may be somewhat exaggerated, but it serves to emphasise the fact that the major shock to Britain's economic structure is likely to be experienced immediately the fighting is at an end in Europe, and it is essential that plans be made accordingly.

Since it would be futile to continue to produce the munitions of war to the same extent, when war with Germany ceases, many contracts should be cancelled, even though a period of unemployment must result. It would be more economical to compensate workers thrown out of employment, but, more important, it would enable plants to put into operation reconstruction plans. One of the industries which will have the least time to effect a transition will be the iron and steel industry. This industry is a basic industry, upon which practically every other industry depends, and after a comparatively short lapse production will be resumed at a high level to supply the raw materials other industries need for their products. Indeed, the iron and steel control will most likely continue to function in order that supplies will be made available in the national interest. Thus, probably more than with any other industry, the iron and steel industry will need to carry out delayed reorganisation and reconstruction, while, at the same time, endeavouring to maintain a high level of production.

It is generally known that the British Iron and Steel Federation, through its Reconstruction Committee, has under consideration not only the transition period immediately after the war, but the whole future of the British iron and steel industry. The problems being tackled are many and complex, and it is believed that expressions of opinion, given elsewhere in this issue, and representative of a cross-section of the industry may be helpful in reaching decisions, which will undoubtedly mean so much not only to the iron and steel industry itself, but to the whole of British industry. The views of a representative authority of an important

The fact that goods made of raw materials in short supply owing to war conditions are advertised in "Metallurgia" should not be taken as an indication that they are necessarily available for export.

consuming industry is also included, because we are convinced that servicing the needs of the major consuming industries tends to promote the best interests of the iron and steel industry, at the same time consuming industries can contribute to economical production of iron and steel in their various forms by a reduction in range and the adherence to standard types.

Foundry pig iron is an important product of the industry, and the views of Dr. Hartley on the prospects of co-operative research to develop the production of ferrous castings will be read with interest. Whether the use of dry blast or an oxygen enriched blast in the blast-furnace are yet economical propositions is worthy of scientific investigation, as pointed out by Mr. Arthur Dorman in his presidential address at the recent annual

meeting of the Iron and Steel Institute. With the advance in the cost of fuel, the possibility of effecting economies by either or both methods is discussed at some length in this issue.

Whilst it will be appreciated that the views expressed by the various contributors are not necessarily endorsed by the Editor, it is felt that freedom of expression aimed at the maximum degree of efficiency of production can only serve a useful purpose. Research is undoubtedly the life-blood of progress, and the successful future of the iron and steel industry depends to a large extent on its ability to foster and make use of technical and scientific research, but much could be done to advance efficiency in production in its widest sense by frank discussion and the pooling of ideas.

## Metals Reserve Programme of U.S.

**T**HE United States is the richest nation in productive capacity of minerals, but is poor in many of the necessary ores, according to Mr. Charles B. Henderson, chairman of the United States Reconstruction Finance Corporation, in a recent speech. Before this war the United States imported substantially all its tin, chrome, manganese, nickel, platinum, asbestos and cobalt, as well as much of its tungsten, mercury, antimony, graphite, mica and vanadium. He did not dwell on the importance of each of these minerals in war production other than to say that each had to be brought into America for processing into weapons and machines of war, and to report that adequate supplies of these minerals have been obtained.

### Tin

World production of tin immediately prior to the war ranged from 150,000 to 200,000 long tons a year. Nearly half was consumed in the U.S. Even though our tin production was entirely negligible, two steps were immediately taken to increase tin supply. One was an agreement with the International Tin Committee, representing the seven major producing countries, to increase the production of tin from the then current rate of 80% to 130% of the standard quotas. The second step was a contract with the Bolivian producers and the Government, under which approximately half of the tin produced in that country would be shipped to the U.S. for smelting. Certain of this ore previously had been shipped from Bolivia to smelters in continental Europe, which were no longer available. Even though substantial tin smelting capacity was then open to us in the Far East, it was felt that this country would be safe with a tin-smelter within our continental limits.

As a result, a tin-smelter, costing over 6,000,000 dollars, was built at Texas City, Texas. The plant has been operating since April, 1942, producing tin of the highest quality. Its output to date has exceeded 41,000 tons, and the present production is approximately 2,500 tons monthly.

### Manganese

The United States' dependence on imported manganese is only slightly less than her dependence on imported tin. Domestic manganese ore production from 1919 through 1939 had averaged about 40,000 long tons a year, compared with normal consumption of between 600,000 and 1,000,000 long tons. That country does possess substantial deposits of manganese ore; unfortunately, however, most of them are of low grade. Because of the huge tonnage required for the defence

programme, it was imperative that metals reserve expand production of manganese in the U.S. Therefore a contract was promptly made for production from the deposits at Butte, Montana, the then largest known commercial source of that mineral in this country. Treatment facilities were built by private capital.

Production from this one source since late 1941 has been at a rate more than double the previous annual production of the U.S. In addition, contracts were given to other companies owning domestic deposits. Buying stations have been established to which a smaller miner can bring his ore for immediate cash sale.

Steps were also taken to increase the manganese production of Cuba, Brazil, Mexico and Chile, the other Western hemisphere sources of this indispensable ingredient of steels. Production in these neighbouring countries, both in 1942 and in 1943, has been more than double their production of 1939. Large quantities have also been obtained from other sources—notably India, South Africa and the Gold Coast.

### Other Metals and Minerals

To date, purchases have been made by Metals Reserve of forty-six different metals and minerals. In addition to those materials, with which all are familiar, such as aluminium, copper, lead and zinc, the list of materials purchased includes such little known products as zirconium, used as a steel hardener, a refractory for furnace linings, and an ingredient in enamel and glass-making—cryolite—brought from Greenland to be used as a flux in the production of aluminium, and rutile, which has made possible the enormous expansion in welding that, in turn, has permitted the States to build ships at a rate never before contemplated.

An essential part of the programme was the negotiations before Pearl Harbour of a series of agreements with Latin-American countries under which a twofold purpose was accomplished:—

1. Those countries agreed to export strategic materials to the U.S. only, or to other countries in the western hemisphere. Thus the Axis was cut off from all critical and strategic materials from the western hemisphere. Japan in particular had been a large importer from Latin-America prior to these agreements.

2. The agreement to buy permitted those countries to expand production. This has been of great value. Agreements covering substantially all their mineral output were negotiated with the Governments of Brazil, Chile, Peru and Mexico. Similar agreements covering specific commodities were negotiated with Bolivia, Argentina and Colombia.

# Malleable Cast Iron

## Part II.—Metallurgical Aspects

By J. A. Wylde

*The author outlined the origin and development of malleable cast iron in the previous article.\* In this article he discusses the metallurgical characteristics of both whiteheart and blackheart types, and describes their production. Comparisons are made of the structures of both types in the unannealed and annealed conditions.*

**A**S explained in the previous article, there are two types of malleable cast iron, whiteheart and blackheart, and as whiteheart was the first to be introduced it is advisable to consider this type first when dealing with the metallurgical aspects of malleable cast iron.

### Whiteheart Malleable Cast Iron

Whiteheart metal in the "as cast" state is a hard and brittle white cast iron. The hard, brittle castings are brought to their malleable state by a process of "annealing" which eliminates the hard carbide of iron by the introduction of an oxidising atmosphere. By this process of oxidation a quantity of the carbon is removed from the castings. A typical "as cast" analysis would be as follows:—

Carbon (total) .....	2.80 to 3.00%
Silicon .....	0.50 " 0.70%
Manganese .....	0.30 " 0.40%
Sulphur .....	0.10 " 0.20%
Phosphorus .....	Not more than 0.10%

It is important that the analysis of the material be carefully controlled, particularly with regard to the carbon and silicon contents. Lack of care in controlling these two elements will result in the formation of graphite in the hard castings. Such a formation would lead to the development of weakness in the "annealed" castings.

The two methods of melting used for the production of whiteheart malleable cast iron are by crucible and cupola, detailed consideration of which will be included in a later section of this series. In the case of high-quality crucible castings, refined hematite pig is generally used, but for lower grade work a varying percentage of hard foundry scrap is added to suit the class of work on hand. The mixture for cupola production usually consists of hematite pig, a percentage of hard foundry scrap and mild steel scrap, according to the analysis desired.

It is not unusual in some whiteheart foundries to run different charges for light and heavy work. In the case of heavy work, a lower silicon content is aimed at to prevent, as far as possible, pregraphitisation taking place during the period of freezing. In the case of lighter work, a higher silicon content is more desirable to facilitate running thin sections. At the same time a careful balance must be preserved, otherwise difficulty will be experienced in annealing.

The coke used in cupola melting has a direct influence on the metal. This fuel is high in carbon and sulphur, and these two elements are picked up by the metal during melting. Limestone is added to the cupola

charges to flux away the coke ash and other non-metallic substances. It prevents the metal, to some extent, from absorbing sulphur by combining with the sulphur to form calcium sulphide which passes into the slag.

### Influence of Constituents

**Carbon.**—In the original mixture it is advisable to keep this content as low as possible, as there is always a tendency for it to increase during melting. This is due to the metal being melted in contact with the coke fuel from which carbon is "picked up." As the process of annealing is one of carbon extraction by oxidation, it does appear that annealing is aided by using a low carbon content in the original mixture.

It must be borne in mind that an increase in carbon lowers the melting temperature and aids fluidity. This constituent must not be reduced unduly, so as to impair free running of the metal during actual casting operations.

**Silicon.**—As the production of a "white" cast iron is essential, the silicon content must be kept as low as possible. This element, together with carbon, is responsible for producing graphite by breaking down the free carbide. If the silicon content is too low, difficulty will be experienced in annealing the white cast iron, due to a stabilisation of the iron carbide. As in the case of carbon, a low silicon content tends to reduce the fluidity of the metal, and causes mis-running in thin sections.

**Sulphur.**—A high sulphur content, even more than silicon, tends to stabilise the iron carbide, and retards annealing of the white iron castings. In cupola practice there is a tendency for this element to increase due to a percentage being "picked up" from the coke during melting. The adverse effects of sulphur can be partly adjusted by a slight increase in the manganese content. Every possible effort should be made to keep this undesirable element at a minimum. In some directions an excess of sulphur is considered contributory to the presence of surface cracks and shrinkage defects, sometimes found in the annealed castings.

**Manganese.**—Manganese is necessary in a limited quantity, as it counteracts the harmful effects of sulphur by forming manganese sulphide. If in excess, manganese carbide is formed, having a pronounced hardening effect upon the annealed castings. The manganese must be controlled in relation to the sulphur content.

**Phosphorus.**—Due to refined hematite pig being used, this constituent gives the malleable founder little trouble. Phosphorus aids fluidity, but it should not be present in excess of 0.1%, otherwise cracking and warping may be experienced during annealing, together with brittleness in the finished article.



Whiteheart malleable, unannealed  $\times 50$ . Free carbon is absent, the whole of the carbon being in the combined form. The structure is pearlite (dark) and free cementite (light).

### Annealing

The term "annealing," as applied to the malleablising of white cast iron, is not strictly correct. Annealing usually refers to a process of normalising the effect of work-hardening or the correction of fatigue. It is only partly correct, as the process serves to relieve casting stresses as in the annealing of steel castings, but its main function is one of decarburisation.

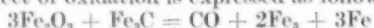
At one time it was thought that the structure of the castings opened out under the action of heat and enabled the oxygen to penetrate, but this theory has since been discredited. The carbon actually migrates from the centre of the casting to the outer decarburised parts, oxidation taking place more rapidly than migration. The carbon, in its original combined state, becomes diffused throughout the casting, but in varying degrees increasing towards the centre. The medium of oxidation is red hematite ore  $\text{Fe}_2\text{O}_3$ . The ore is broken down, or kibbled, into pieces about the size of small gravel and mixed with a percentage of ore that has been used previously.

As will be described later, the castings are tightly packed with ore in annealing pots and sealed in the annealing oven. The temperature of the oven is increased slowly and evenly to avoid uneven expansion of varying sections, as any rapid fluctuation would cause the castings to crack and distort.

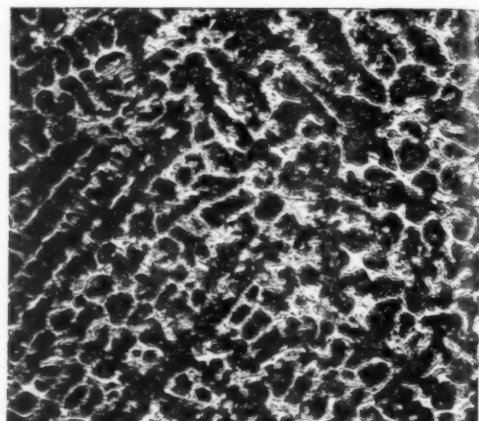
The "as-cast" structure of the metal is a combination of free iron carbide and pearlite. At approximately  $730^\circ\text{C}$ . the ferrite commences to take the free carbide into solution and this procedure accelerates as the temperature increases to a maximum of  $950^\circ$  to  $1,000^\circ\text{C}$ .

As this change takes place, carbon is being removed from the outer skin by the oxidising agent, causing a decrease in the concentration of iron carbide in solution in this area. More is taken up from the adjoining layers now richer in carbide, causing a gradual diffusion from the centre to the outer surface. The carbide is gradually oxidised away until the oxidising action of the ore is exhausted.

The effect of oxidation is expressed as follows:—



The period of annealing is governed to some extent by the design of work being treated, especially by



Blackheart malleable, unannealed,  $\times 50$ . The structure is free from graphite and is composed of pearlite and cementite, but the grain size is larger and the ratio of cementite to pearlite is much less than in unannealed white heart malleable, due to lower total carbon content.

the sectional thickness, and may vary from 100 to 200 hours.

It is important to stress that the original carbon content is reduced by annealing, but that the remaining carbon is still in the combined state. Carbon may be completely eliminated from the thin sections, but its total removal from the thicker sections is practically impossible. Here lies the main difference between whiteheart and blackheart material.

Due to the presence of pearlite, whiteheart may have, in some instances, a higher tensile strength and harder wearing properties than blackheart. It will not compare with blackheart for consistency, ductility and machinability. A comparison of the main physical properties is given later.

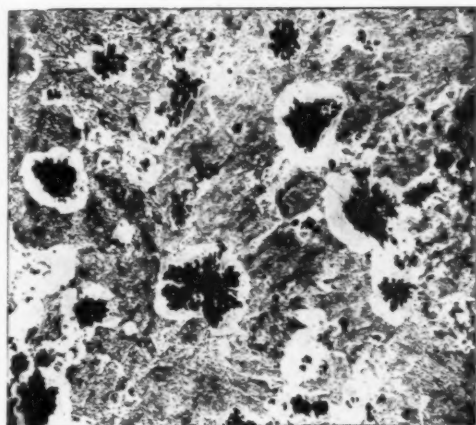
### Blackheart Malleable Cast Iron

In certain respects the blackheart process bears a resemblance to the whiteheart process. In both cases a hard, white cast iron is necessary, and the desired action of "annealing" is to break down the free iron-carbide compound. It will be seen that apart from the variation in analysis, the main difference between the two processes is in the "annealing." The state of the carbon after annealing is responsible for the variations in texture and colour of the fractures, from which the two materials obtain their names.

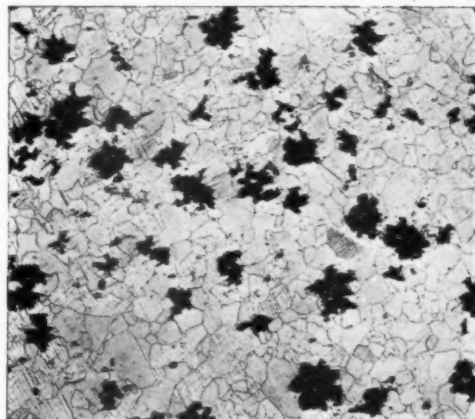
Accurate metallurgical control is more essential with blackheart malleable than with whiteheart. Due to its reliable nature, blackheart is the material from which most heavy castings are made. With heavy castings the possibility of pre-graphitisation will be more pronounced and must be carefully guarded against.

When previously discussing whiteheart, attention was drawn to the effects of carbon and silicon. It is essential that these two elements should be even more finely controlled in the case of blackheart. A typical "as-cast" analysis for blackheart malleable iron would be as follows:—

Total carbon	2.30 to 2.70%
Silicon	0.70 " 1.10%
Manganese	0.25 " 0.40%
Sulphur	Not more than 0.10%
Phosphorus	" " 0.10%



Whiteheart malleable, annealed,  $\times 50$ . Taken from the centre of a well-annealed 2 in. diameter section. The black patches are temper carbon (graphite). They are surrounded by lakes of ferrite (white). The matrix is pearlite (half-tone), distinctly laminated in the left-hand top corner. Sulphides are seen as grey particles in both pearlite and ferrite.



Blackheart malleable, annealed,  $\times 50$ . Taken from centre of 3 in. diameter section. The structure is ferrite and temper carbon. A few sulphide particles may be seen. There is no combined carbon present.

Simply expressed, the metallurgical function of the blackheart process is to produce graphite-free castings, and to subject them to reheating at a temperature that will separate the free carbon in the form of finely divided temper carbon. There is no chemical difference between graphite and temper carbon, graphite being in the form of crystalline flakes and temper carbon being in an "amorphous" form. The flakey graphite forms approximately at the eutectic freezing point, while temper carbon forms in the reheated iron at a much lower temperature. The effect of reheating a partly graphitised casting will cause a breaking down in the structure of the casting in the pre-graphitised areas.

Nearly all blackheart material is produced in melting units, such as the air furnace, open-hearth, rotary and electric furnaces. Melting is carried out without the metal coming in contact with fuel. It is possible to produce a more homogeneous metal, and one consistent in chemical and physical properties, which could not be expected by cupola melting. Both carbon and sulphur contents will bear a stricter relationship to the original mix, making the necessary allowances for melting losses.

Open-hearth and air furnaces enable the charges of raw materials to be thoroughly mixed, but there is no guarantee of this taking place in normal cupola practice.

Metallurgical control is simplified by the use of more efficient melting methods, as used in blackheart production, but the constituents require to be retained within finer limits than in whiteheart production.

#### Influence of Constituents

**Carbon.**—The carbon content should be controlled between 2.40 and 2.70%, and as this is lower than whiteheart, it is necessary to cast blackheart at a higher temperature. Should the carbon fall below the minimum, difficulty will be experienced in the foundry in running the castings. If the carbon is increased above the maximum, the strength of the resultant castings is reduced.

With the carbon increase comes an increase in the distribution of graphite areas. These graphite areas or

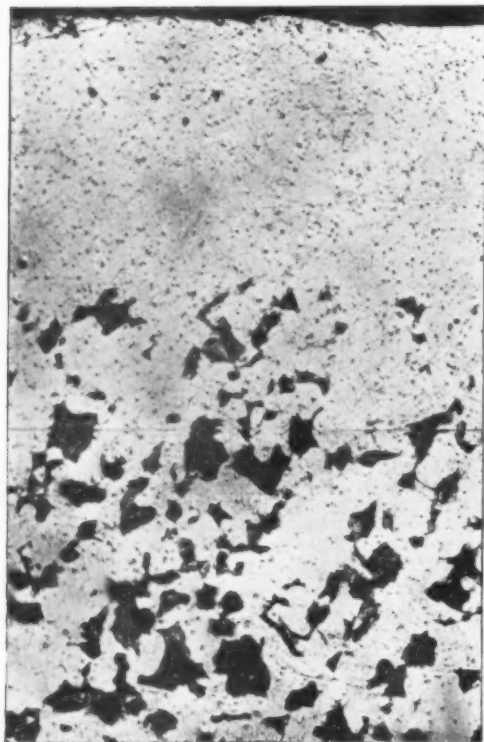
"rosettes" of temper carbon break up the strong formation of ferrite and, if in excess, weaken the structure of the metal. The fine distribution of temper carbon in blackheart malleable may be contrasted with the flakey graphite formation in grey cast iron, and the pearlitic state of whiteheart malleable. This fine distribution of the carbon is mainly responsible for the superiority of blackheart over whiteheart or grey iron, and for its free machining quality.

**Silicon.**—It is usual to vary this element between 0.70 and 1.10%. A general rule is to vary the silicon content inversely with the carbon, as it is the combined effect of these two elements which brings about graphitisation. Excess silicon, especially in heavy sections, will cause graphitisation in the "as-cast" state, rendering the material little better than ordinary grey iron.

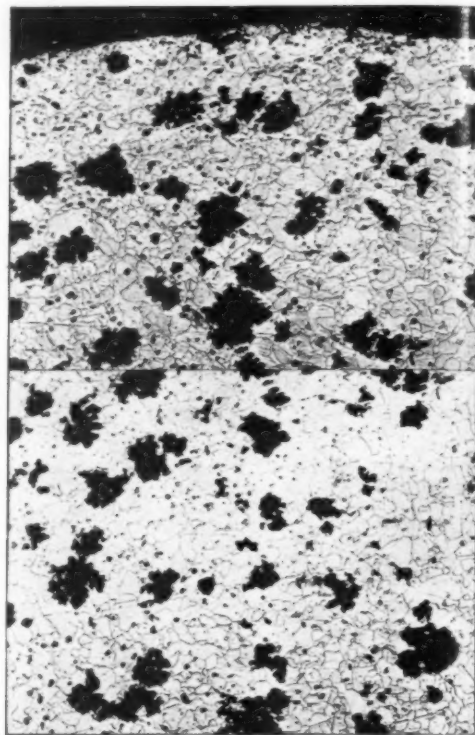
As previously explained, if the silicon is too low, annealing is retarded. It is a good practice, when producing heavy castings, to keep the silicon at a practical minimum, and balance with an increase in carbon. If the desired silicon content is 0.90% a carbon content of 2.40% could be used with safety, but if the silicon is reduced to 0.70% a balance may be maintained by increasing the carbon to 2.80%.

**Manganese.**—This element should be present in sufficient quantity, varying between 0.20% and 0.50%, to balance the sulphur content. The effect of manganese in the presence of sulphur, in correct proportion, is to form manganese sulphide. This formation counteracts the adverse effects of sulphur and prevents the formation of iron sulphide. Manganese carbide is formed, which retards graphitisation if manganese is present in excess.

**Sulphur.**—The simple rule for sulphur is to keep it as low as possible. Sulphur has been made a kind of malleable ironfounders' "bogey man." Although it would be unwise to underrate the danger of this very undesirable element, its main disadvantages have been satisfactorily overcome. The wise metallurgist will not condemn a casting purely upon the grounds of a high sulphur content without giving due consideration to the physical properties of the castings. Material with a sulphur content of 0.20% will give test results well in



Whiteheart malleable, annealed,  $\times 50$ . Taken from the edge towards the centre of a  $\frac{1}{8}$  in. section. There is a band of ferrite next to the skin which contains sulphides, oxides and silicates, and temper carbon. The structure within the surface layer of ferrite is pearlite and ferrite with some temper carbon and sulphides.



Blackheart malleable, annealed,  $\times 50$ . Taken from edge of  $\frac{1}{8}$  in. diameter section. The structure is ferrite with temper carbon. Traces of sulphides may be detected with difficulty. There is no combined carbon present.

excess of the standard specification, providing the manganese content has been satisfactorily adjusted. In good blackheart practice sulphur should be retained at 0.10% or lower. By electric melting and desulphurising, the Americans have produced castings with a sulphur content of 0.01% without any commercial advantage being gained.

Sulphur, if uncontrolled, stabilises the iron carbide and prevents the formation of temper carbon.

**Phosphorus.**—No trouble will be experienced with this element if phosphorus is maintained at 0.10%. As good supplies of low phosphorus pig are always available, little trouble is experienced in this direction by the malleable founder. Phosphorus has no effect on the annealing process, provided it is kept fairly low, but an excess will reveal extreme brittleness and cause warping in the annealed castings.

In scrap purchased from outside sources, the foundry chemist must be constantly on the watch for obscure elements, such as chromium, as only a minute quantity may upset the most careful calculations due to its powerful effect in stabilising carbide.

### Annealing

The castings are packed in iron boxes or cans, as in the whiteheart process, and the ovens used are of similar construction. As the packing medium does not affect the process, any inert substance, such as black

foundry sand, loam, pan-sealing or crushed slag can be used. It is possible to anneal by the blackheart process without packing material, but such a procedure would lead to unnecessary distortion of the castings. Care must be taken to ensure the castings being completely sealed to prevent oxidation taking place during annealing.

The process of annealing can be split into two distinct stages. The first stage consists of heating the castings and soaking them at the desired temperature. At this stage graphitisation takes place. The second stage is a slow cooling-down process, during which graphitisation is completed.

In stage one the temperature is increased slowly, and at about 750° C. a change takes place in the pearlite structure of the metal. The cementite or iron carbide portion of the pearlite is taken into solution by the ferrite to form austenite. This new constituent is a homogeneous solid solution of iron carbide in iron. It is capable of taking increasing quantities of carbon into solution as the annealing temperature increases. Up to a temperature of 840° to 880° C. the austenite continues to absorb carbon until a point of saturation is reached. The temperature is held constant, and during the soaking stage the austenite deposits the absorbed carbon in the form of temper carbon nuclei.

As the temper carbon is deposited, the carbon concentration in the austenite is lowered. The austenite is then able to absorb further carbon from the iron carbide until a point of saturation is again reached. The process of carbon absorption and deposition of

(Continued on page 129)

# "Strength" in Technical Parlance

By A. C. Vivian, B.A., D.Sc., A.R.S.M.

*The term "strength" is in general used so frequently for different purposes that its meaning has become somewhat confused; even descriptions by technicians are vague, yet in its application to metals it is important that there should be no ambiguity in its use concerning the property of the metal or alloy under consideration. In order to overcome confusion of thought on the subject, the author presents and discusses a proposal for the use of the word in technology.*

**T**HAT quality in a material conveyed by the word "strength" has been an important conception from time immemorial. Cardinal though the idea behind strength is felt to be, the word has become hazy in meaning, so vague that various descriptions of it can be obtained from technicians.

Such a state of affairs can partly be excused on grounds that certain closely specified qualities of materials are now measured, and can therefore be cited in lieu of this quite general quality "strength." It is noticeable, however, that the whole question as to what constitutes strength in general, and which of the more recently defined qualities legitimately come under that heading has been left improperly answered. This cannot be satisfactory; in any study of the kind the existence at its core of such a germ of ambiguity is enough to permit individuals to harbour vagrant notions, and to develop confusion of thought on the subject.

The dictionary definition, a medley of force, work and power, is useless to the technical man. It was ever thus that dictionary meanings become outlived as guides to words which have been imported into technology. The latitude in the use of words by the general public is much greater than that permissible in a study into which the words have been introduced as "terms."

## Strength under Analysis

A conception can only be accurately formulated for a technology and accepted if it survives the practical test, the actual test being the only proof that the conception is sound. The old Phlogiston theory of matter, for example, was a conception which had to be abandoned upon the failure of tests to support it. Similarly, practical tests can condemn or uphold original conceptions of a material's qualities, or they can modify it as the case may be. The practical tests on materials have taught a great deal in the last half-century; the old conception of strength having been analysed into component parts. The single old meaning for the technical man has been displaced by a plurality of new meanings; and yet the word "strength" is still freely used in spite of the fact that no one is quite sure which of the many possible meanings, or what combination of them, is to be conveyed thereby. The testing of materials is now emerging into the light of a day in which it is possible to attach a particular meaning to "strength" as a certain cardinal property or quality of a material.

Tests of materials have shown that, on increasing the force or load on a specimen, a graph can be drawn which is characteristic of that material's reactions to force, and portrays its behaviour under loading in general. This graph is drawn between the intensity of the load (the

stress) and the change in unit of length (the strain). As the force on the specimen increases, step by step it can be calculated as a stress—i.e., load per unit of cross-sectional area. As the change in length takes place, step by step it can be calculated as the total of all the changes of length per unit of previous length—this type of strain having important advantages over the more usual type employed. Such a "stress-strain curve" of a material is almost a complete picture of the mechanical properties of the material.

## The Components of Strength

It will be seen from this curve that the elastic modulus is the slope of the first nearly straight portion of the curve: anywhere on this straight part, the stress ( $f$ ) and the strain ( $s$ ) can be read, when  $f/s = E$  (Young's modulus of elasticity). The limit of proportionality is the stress at the top of the straight line of elastic reaction. The elastic limit, yield stress, and the proof stresses are read at points above the limit of proportionality because they mark other specified limits of elastic or nearly elastic reaction. Beyond all these, the curve bends over fairly sharply, and then becomes straighter again, the region whence the second fairly straight portion springs being significant as the beginning of the purely plastic reaction of the material. The curve ends at the point from which the property of fracture stress may be read; whilst the strain at this end-point is the usual measure of such properties as ductility and malleability—in general, of "plasticity." The area under this curve is the toughness, the energy required to take one cubic unit of the material up to rupture point.

## Combinations of Components—Hardness

Whilst all the foregoing properties are exhibited by a material subjected to direct single loading, the property of hardness is only exhibited upon loading of a compounded and more complex type. In hardness loading, a compressive force is applied locally on the surface of the mass of material, not all over the surface as in simple compression; and the usual sideways expansion under this force is checked by the force of the resistance of the surrounding material. Under such conditions, the curve of stress-strain is always steeper, of steepness depending mainly on the amount of the lateral restriction to the local loading; until, if the sideways force offered by the surrounding material were to be great enough to stop all lateral expansion whatsoever, the curve would be just a very steep straight line. Hardness depends on the degree of steepness to be provided by the sideways resistance of the surrounding material added to the steepness of the plain stress-strain curve.

Now the original and the present-day conception of hardness is the quality by which a material resists penetration, scratching, abrasion or wear. The favourite test falls into line: a small hard ball or a pointed tool is forced into the surface by a fixed load, and the intensity of the material's resistance to penetration is a measure of this hardness. As thus conceived and tested, hardness proves to depend on a combination of the fundamental properties as above: itself it is not fundamental, even though it may be conceived to be primary and elementary. It has been recognised as some kind of strength, and it will be clearer from the following what kind of strength it is. At present the chief point is that hardness proves on analysis to be complex; therefore it would not be found on the stress-strain curve of the fundamental properties. Hardness can be conveniently measured by a certain test: in reality, the scientific way of ascertaining hardness would be by means of calculations from known fundamental properties.

### Fatigue Endurance

A similar argument applies also to the case of the property known as "fatigue endurance." Upon repeated loading, a certain damaging effect is produced with a great number of repetitions of very small loads; and the ability of a material to stand up against this insidious kind of loading is its fatigue endurance. It is not a fundamental property even though it is so important; it is another complex of which its components only can be read direct from the stress-strain curve. It is measured as a whole by a certain test; but it should be capable of calculation from properties of the stress-strain curve.

### A Simile

In the above respects, hardness and fatigue endurance can be likened to the "compressibility" of a spring; this can be measured direct by a test, or it can be calculated. The components of, and all the calculations for, the compressibility of a spring are thoroughly well known; and, even so, the direct measurement is sometimes preferred to the calculation. As yet, no one is very sure how to calculate either for hardness or fatigue endurance, so direct measurements are necessary for these properties to-day, though presumably they will not always be necessary. The direct measurement of the compressibility of a spring is an admission of failure to produce uniform homogeneous spring materials to accurate specifications of their stress-strain curves. Direct measurements of hardness and endurance are more serious admissions that there is no certainty as yet what the components of these properties are; methods of calculation are necessarily lacking as well.

In a somewhat similar way, notch toughness by the shock tests is a criterion of a material's ability to resist damage from sudden blows, or from slower loading at some notch or re-entrant angle. The tests are easy to carry out, and they afford guidance in the choice of materials to resist impact. This is another property which is no more fundamental than the compressibility of a spring; in time, when more is known about it, notch toughness will be calculated more accurately than it is at present measured direct.

### A Classification of Strength's Components

If it has been established that the stress-strain curve is the authentic and complete picture of all elementary reactions to loading, and that those properties which do

not appear on the curve are merely compounds or derivatives, then it becomes clear that the irreducible but satisfying minimum of these fundamental properties can be classed in a certain way. For some are measured by reference to the *stress* axis of the curve, some by reference to the *strain* axis, and the remainder are in terms of *stress multiplied by strain*—i.e., by reference to the area under the curve which represents the work done on unit volume up to any desired stress and strain. Hardness and fatigue endurance are both measured as stresses; and it is found that there are strong bonds of relationship between these properties and the "stress properties" of the curve; they can be regarded as stress properties themselves. Notch toughness is measured in terms of work like ordinary toughness, and can be classed as a stress-strain property even though it is only derived from such fundamentals.

### A Review

Passing now to an abbreviated review of the position with regard to this word "strength," it would be seen that in earliest times strength stood for what was held to be the unique elementary property of resistance to rupture. Experience with materials showed that such resistance was capable of analysis into stages; that strength was more complex than it seemed at first to be. More recently it has become obvious that the elements of which this compounded property is composed can be classed as "stress properties," "strain properties" and "stress-strain properties."

How, then, should the word "strength" be used nowadays? Has it become meaningless for ever to the technical man? Is it to stand for each and/or all components into which it has been analysed? Can something of the earliest sense of the word be recaptured upon applying it for a particular purpose?

Although use is frequently made of expressions such as "the strength of materials" and "strength properties," the word seems to be unfittingly employed in cases of this kind, in which strength is supposed to include strain properties like malleability or ductility, the possession of which by materials is so often the very denial of strength in its old-fashioned sense. For materials possessing plasticity to a greater degree are just those which offer less resistance to fracture, and are lacking in old-fashioned strength. Nor is it very satisfactory that "strength" should include toughness, seeing that some of the toughest materials rely more on plasticity than on resistance to make them tough. It would therefore appear that if a cardinal word like "strength" were to find any place at all in the modern terminology of the mechanical properties, it should never imply strain properties or stress-strain properties.

### A Choice

Strength might very suitably be allowed to mean the stress properties however, and, if so, "strength, plasticity and toughness" would then refer to the three classes of properties into which old-fashioned strength has been analysed in the last half-century.

Such a use of the word satisfies the most reasonable of all the technical definitions now employed. All the stress properties, not excluding the compound properties hardness and fatigue endurance, are in fact "a material's specific reactions to deformation by force" at different stages and/or under particular conditions of loading.

The stress of Young's modulus is the strength developed (per unit of deformation) in the perfectly elastic range. The strength of the elastic limit is the specific resistance to deformation at the maximum of elastic loading. Similarly, all the other properties measured in terms of stress can be described as strengths. Hardness, a compound property, in reality only refers to strength enhanced in effect by the peculiar manner of loading eliciting hardness phenomena: the material is enabled to offer resistance to deformation, its strength, from three principal directions instead of one. If "strength" is used as a term in connection with the fundamental properties of the simple stress-strain curve, then hardness can be viewed as that same strength exerted in three directions at the same time, and does not call for a separate and distinct variety of strength at all. Fatigue endurance is the strength of resistance to fracture under common but complex conditions of load repetitions, whereby potential and incipient flaws or local weaknesses are developed and propagated. Under repetition loading, fracture would seem to occur at strengths far below that exhibited under one steadily raised load. This is an appearance only: in reality, exactly the same fracture strength is being exhibited at the root of cracks where the material's fracture is actually taking place, such fracture stress being the result of the magnification of much lower stresses by a high leverage factor operating at the root of the cracks.

#### A Short Cut to the Same Choice

Whereas the above explanation in terms of the recognised mechanical properties has been neither short nor simple, the easier way to describe "strength" in the sense chosen in the foregoing paragraph is to repre-

sent it as the *steepness and height* of the stress-strain curve. This is a neater conception of strength, and will fall into line with the suggestion that the word refers to the stress properties because, wherever strength is high, stress properties are high, and vice versa. According to this same view, the length of the stress-strain curve represents the plasticity of the material, and the area under the curve—consisting of steepness, height and length combined—is the toughness. To strengthen the material is but to steepen the curve; to take a stronger material is either to take a material with a steeper curve, or one with a higher curve.

#### Mathematical Parlance

It seems that these stress-strain curves are of the general formula—

$$f = k \cdot s^m$$

which means that, at every point of the curve  $f$  the stress can be calculated from  $s$ , the strain, if two constants for each curve are known—namely  $k$  and  $m$ . Whilst the height of any such curve is determined by the value of the constant  $k$ , the steepness at its commencement is determined by the constant  $m$ . The denser materials, or materials at low temperatures, have higher  $k$  values, and vice versa; various treatments of a material with certain  $k$  value will be found to give rise to change of the  $m$  value which changes the ratio of the stress properties of the more elastic part of the curve with those of the more plastic part—thus raising, for example, the ratio which the elastic limit bears to the fracture stress.

Strength is highest all round, then, with highest possible  $k$  value and lowest  $m$  value. Raising the  $m$  value lowers elastic properties by comparison with the plastic properties, and vice versa.

### Malleable Cast Iron

(continued from page 126)

temper carbon continues until the carbon in the cementite is exhausted.

At the end of stage one, a certain amount of carbon still remains in solution in the austenite.

The duration of the soaking period is 50 to 60 hours, which is generally sufficient to remove all cementite.

The object of stage two, which starts at the end of the soaking period, is to enable the austenite to deposit the carbon still remaining in solution. This is achieved by slowly cooling to the critical temperature of 730° to 740° C. The carbon is deposited as its solubility becomes progressively lower. At the critical temperature there still remains in the austenite the quantity of carbon in the pearlite of the original white iron. This carbon is precipitated by slow process of cooling from the critical temperature to 680° C. From 680° C. cooling may then be fairly rapid.

The resultant structure of the annealed metal is one of pure ferrite grains interspersed with "rosettes" of temper carbon. It is this fine division of the carbon which gives blackheart the free cutting quality for which it is renowned.

#### COMPARATIVE PHYSICAL PROPERTIES OF WHITEHEART AND BLACKHEART MALLEABLE CAST IRON.

<i>Whiteheart, B.S.S. 309/1927.</i>	
Ultimate tensile strength .....	20 tons per sq. in.
Elongation .....	5%
Bend test .....	45° on 2 in. dia.
<i>Blackheart, B.S.S. 310/1927.</i>	
Ultimate tensile strength .....	20 tons per sq. in.
Elongation .....	7½%
Bend test .....	90° on 2 in.

The standard test figures shown are easily satisfied by all reputable malleable foundries. Considerably higher tensile figures are often obtained in whiteheart material than shown, but there is invariably a decrease in the elongation figure. Tensile figures commonly obtained with blackheart vary between 22 and 26 tons per sq. in., with an elongation of 10 to 14%. As in the case of whiteheart, any abnormal increase in tensile is accompanied by a reduction in the elongation figure.

The writers' view is that a well-balanced blackheart material with a tensile strength of 23–24 tons per sq. in. gives a fair indication that its ductility and machinability are in accordance with the best practice. The respective properties and applications of the two materials will be dealt with fully in a later article.

The author wishes to express his thanks to the Council of the Institute of British Foundrymen for the loan of slides from which the photomicrographs in this article have been reproduced.

(to be continued).

THE Council of the British Cast Iron Research Association has approved of the setting up as from July 1, 1944, of a new department of the Association, the Building Uses Department. This has been possible through the far-sighted view of the British Ironfounders' Association. The department will be in charge of a consulting architect, Mr. Derek Bridgwater, B.Arch., F.R.I.B.A., on a part-time basis. It is hoped that a similar department for the engineering and industrial uses of cast iron will be practicable at a later date.

# The Rare Earths

By R. C. Vickery, Ph.D., M.Sc.

*A survey is given of the present position of the chemistry of the rare earth elements. Their nature is summarised and a general account given of methods of separation, identification and determination. Existing problems are considered, and many references to original work are given.*

WHEN presenting a survey of this character, it is customary to introduce the subject with an historical account, giving dates and data. It is not intended, however, in this instance to devote time and attention to the relating of stereotyped passages from a "History of Chemistry"; rather is it the design of the author to give a general account of the rare earth elements, and an indication of the trends of thought and research upon the subject.

## Group Characteristics

Originally, the term "rare earths" was discreetly employed as camouflage for any oxides, metals or salts about which little was known, either generally or by the author of any specific paper. With increasing knowledge and integrity, however, the position has been reached at which the title of "rare earth elements" is now correctly bestowed upon some fourteen elements—i.e., those whose atomic numbers range from 58 to 71, and whose atomic weights are between 140 and 175. This is covered by the VIth (long) period of group IIIA of the Periodic system. The inclusion in the rare earth group, by some authors, of such elements as scandium, lanthanum or yttrium, on the basis of group segregation, or of thorium on grounds of association in occurrence, is to be deprecated as hardly in accord with the rulings of the Periodic law as now understood. The "asteroid" theory of Brauner<sup>1</sup> and the "lanthanide contraction" of von Hevesey and Goldschmidt<sup>2</sup> have led, in recent years, to a better understanding of the position of the rare earth elements in the Periodic system; thus it is considered that the series of elements between lanthanum and hafnium are a transition series in which the elements are successively synthesised by the introduction of electrons into an inner quantum group of the atom, and by addition of protons and neutrons to the nucleus. As the elements lanthanum and hafnium represent the boundaries of the sequence, they cannot therefore be included in the rare earth series proper. According to Mellor,<sup>3</sup> the rare earth group consists of the elements from cerium to ytterbium inclusive, and is foreshadowed by scandium and yttrium, which precede lanthanum in the vertical series as starting-points of the first and second transition series.

The remarkable similarity in properties of all the rare earth elements is thus seen to be due to the fact that their ultimate and penultimate electron groups are all identical. The incompleteness of the inner quantum group is shown, in the rare earths, by their characteristic absorption at the violet end of the spectrum, by the

colours of their oxides and salts, and by the paramagnetic properties of their compounds— $\text{Dy}_2\text{O}_3$  is stated<sup>4</sup> to be twelve times as paramagnetic as  $\text{Fe}_2\text{O}_3$ , and Levy<sup>5</sup> shows a table modified from Urbain and Jantsch, in which the magnetic susceptibilities of the rare earths are seen to reach a minimum at samarium with a very sharp rise on either side (Table I). Erbium, thulium, ytterbium and lutecium appear in descending order at the end of the series, but no figures are given. The coefficients for dysprosia, erbia and gadolinia were found to increase rapidly with reduction of temperature, whilst Cabrera<sup>6</sup> has pointed out the influence of occluded water upon the magnetic constants.

Nd.	Sa.	Eu.	Gd.	Tb.	Dy.
33.5	6.5	33.5	161	237	250

The radio-activity shown by the rare earths has evinced curiosity from the earliest times, and Spencer, writing in 1919, said:<sup>7</sup> "The constant presence of radio-active material with the rare earths is a noteworthy fact"; and many workers have attempted to isolate the radio-active portion. Von Hevesey and Pahl were of the opinion, however,<sup>8</sup> that the radio-activity displayed by many rare earths was due to contamination by radio-active elements. Mazza and his co-workers<sup>9</sup> examined the products of intense fractionation of the rare earths, and stated that all fractions containing La, Ce and Sm were very radio-active, whilst those containing Pr and Nd were only partly so. By fractional crystallisation of the double ammonium nitrates, they concentrated in the less soluble La fraction a considerable part of the activity originally present, and further investigations then indicated that traces of known radio-active elements are tenaciously held by La. The same was found to be true for Ce, whilst the radio-activity of the Nd-Sm fraction was considered to be in accord with the probable activity of these two elements.

## Occurrence

The occurrence of the rare earths, usually as complex silicates, phosphates, zirconates, etc., is widespread, but deposits of minerals containing them are rarely available in quantities sufficient to warrant commercial exploitation. Although the raw materials employed for the extraction depend upon the actual elements required in the final products, monazite is the main source of the metals in general, and though essentially an orthophosphate of the cerium earths, it is worked commercially for its thorium content, which may be as high

<sup>1</sup> Z. Elektrochem., **14**, 525, 1908.

<sup>2</sup> Z. Anorg. Chem., **147**, 217, 1925; "Geochemische Verteilungsgesetze" Oslo, 1925.

<sup>3</sup> "Modern Inorganic Chemistry." London, 1943.

<sup>4</sup> Morgan and Bursall. "Inorganic Chemistry." London, 1936.

<sup>5</sup> "The Rare Earths." London, 1924.

<sup>6</sup> Compt. Rend., **207**, 1077, 1938.

<sup>7</sup> "The Metals of the Rare Earths." London, 1919.

<sup>8</sup> Z. Phys. Chem., **164**, 147, 1934.

<sup>9</sup> Mazza et al. Gazz. chim. ital., **65**, 995, 1908, 1935.

as 20%. Occasionally found massive and as granular veins in granite, associated with wolframite, cassiterite, etc., the more usual occurrence is as an accessory constituent of pre-Mesozoic rocks of the granitic type (generally having undergone pegmatitic alteration), whence weathering processes produce the monazite sands, which may thus be regarded as Nature's attempt at the concentration of the heavier accessory constituents of the parent rock. Thus monazite sands contain, in addition to granules of the name mineral, grains also of zircon, apatite, rutile, ilmenite, sphene, garnet, epidote, sillimanite, tourmaline, gadolinite, allanite, etc. Primary minerals, such as magnetite, quartz and hematite, are also present, whilst where the parent rocks have been auriferous, the sands contain gold also. A point worthy of note is the conclusion of Querke and Kremers<sup>10</sup> that high-temperature epidotes and apatite may be regarded as test minerals for the presence of the rare earths.

The number of other rare earth minerals of economic importance is not particularly great, although Browning<sup>11</sup> tabulated about 100 different species. Commercially, however, apart from monazite, the only minerals worthy of separate consideration are allanite, cerite, euxenite, fergusonite, gadolinite, polycrase and samarskite.

### Methods of Separation

The individuality of the rare earth minerals lasts only as far as concentration and solution are concerned. Once in solution, which may be effected by acid digestion or by fusion with pyrosulphate, etc., the rare earths are extracted by precipitation as oxalates from weakly acid solutions after removal of the metals of groups I and II by HCl and H<sub>2</sub>S treatment. Thorium, lanthanum, scandium and yttrium are also precipitated in the oxalate treatment, but in the case of Th, this is removed by virtue of the solubility of Th(C<sub>2</sub>O<sub>4</sub>)<sub>2</sub> in ammoniacal solutions of the ammonium salt, or by prior precipitation as the basic thiosulphate by Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>, or as the peroxyhydroxide Th(OH)<sub>4</sub>(O.OH) by BaO<sub>2</sub> from acid solution. In addition, Ismail and Harwood<sup>12</sup> have devised a separation of Th from the rare earths employing hexamine to precipitate the element as the hydroxide. Precipitation of the hydroxide by a mixture of La and didymium hydroxides has also been commercially employed<sup>13</sup> as a step in the extraction of the rare earths from various minerals.

TABLE II.

Solubility in saturated K <sub>2</sub> SO <sub>4</sub>	Family.	Members.
Insoluble .....	Cerium	Ce, Sm, Nd, Pr (Th, La, Sc)
Mod. soluble .....	Terbium	Eu, Gd, Tb
Readily soluble .....	Erbium	Dy, Er, Ho, Tm
	Yttrium	Yb, La (Y)

After the removal of thorium, the rare earths are obtained as either the chlorides or nitrates in solution, and it is from this point that the difficulties of separation begin. In the early days of research, attempts were made to provide schemes of rare earth separation based upon the solubilities of the oxalates in saturated K<sub>2</sub>SO<sub>4</sub> solution (Table II). This system had several disadvantages, however; the separation of the families is

not particularly well defined, as evidenced by the intermediate terbium group; further, unless originally absent or removed by prior precipitation, several elements not of the rare earth group will be included in the family separations. It is probably this latter fact which led earlier workers to include Th, Sc, Y, etc., in the rare earth group. The most obvious method of separation—that of fractional precipitation based upon the inverse relationship of basicity to atomic weight—was then applied to several workers, and from data accumulated, James, with his co-workers, in a series of researches, produced a system of fractional crystallisations and precipitations of double nitrates, bromates, ethyl sulphates, etc.,<sup>14</sup> which is given here as Table III.

From James' scheme, and the work of other chemists, several methods of separation have been devised, not all applicable to complex mixtures of the rare earth elements, but rather to the purification of crude and semi-pure salts obtained by other methods; in any case, operations for purification have to be repeated many times before anything approximating purity is reached. It is not proposed to list every method put forward for separation of the elements, but rather to indicate what methods have been found practicable, and in what direction the trend of investigation is leading. Four groups of methods have been suggested: Fractional crystallisation; fractional precipitation; oxidation processes; and physical methods.

### 1. Methods of Fractional Crystallisation

(i) *As Sulphates*.—This method is dependent upon the lesser degree of solubility of the simple sulphates in hot water than in cold. Thus, on heating a cold-saturated solution of the anhydrous sulphate, a crystalline hydrate separates with the composition M<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>·H<sub>2</sub>O. Although by this process thorium is easily freed of the rare earths, Wyruboff and Verneuil showed<sup>15</sup> that the converse is not true, the method failing to remove the last traces of thorium or lanthanum from the cerium earths.

(ii) *As Alkali Double Sulphates*.—This is a commonly employed method, similar to the old one based upon the varying solubilities of the oxalates; in this case, however, the separation depends upon the differences in solubilities of the double alkaline sulphates in saturated solution of that alkali sulphate. The method of James (*vide* Table III) has this procedure as its first step, in which Ce, Pr, Nd, Sm, Eu and Gd are separated from Ho, Yb, Dy, Tb, Er, Tm, Lu, etc.

(iii) *As Nitrates*.—For elements whose atomic weights are greater than that of dysprosium, crystallisation of the mixed nitrates from HNO<sub>3</sub> of 1.3–1.54 sp. gr. gives good results. This is based upon the fact that the solubility of the nitrates in nitric acid solution decreases with increasing atomic weight to a minimum at Gd after which the solubility becomes directly proportional to the atomic weight and reaches a maximum at Yb. Harris and Wylie have stated<sup>16</sup> that the nitrates afford a means of rapid concentration of Eu, Tb and Gd, from a general mixture of the earths, and in the first decade or so of the present century, several exhaustive investigations were made of this method, Urbain<sup>17</sup> carrying out some 15,000 fractionations to separate Lu from Yb. At the

<sup>14</sup> *J. Am. Chem. Soc.*, **30**, 182, 979, 1908; **31**, 913, 1909; **32**, 517, 873, 1910; **33**, 1332, 1363, 1911; **34**, 757, 1912; **36**, 643, 1914.

<sup>15</sup> *Compt. Rend.*, **128**, 1331, 1899.

<sup>16</sup> *Tr. Roy. Soc. Canada*, **28** (III), 63, 1932.

<sup>17</sup> *Compt. Rend.*, **145**, 738, 1907; **150**, 323, 1914.

<sup>18</sup> *J. Am. Chem. Soc.*, **34**, 1174, 1912.

<sup>10</sup> *Econ. Geol.*, **35**, 173, 1943.

<sup>11</sup> "Introduction to the Rarer Elements." New York, 1917.

<sup>12</sup> *Analyst*, **62**, 135, 1937.

<sup>13</sup> *Brit. Pat. Spec.*, 510,198, 1939.

TABLE III (AFTER JAMES).<sup>14</sup> Figures in parenthesis indicate succeeding operations.  
The solution of the rare earth is treated with a saturated solution of  $\text{Na}_2\text{SO}_4$  or the solid salt. (1, 2.)

1. Precipitate: Double Na sulphates of Ce (La) Pr, Nd, Sm, Eu and Gd, with traces of Tb, Dy, etc. Convert to nitrates and boil with $\text{KBrO}_3$ and marble chips. (3, 4.)							2. Solution: Contains Tb, Dy, Ho (Y), Er, Tm, Yb, Lu (Hf) with traces of Sc, Gd, Eu and Sm. Convert to oxalates, then via sulphates into bromates and fractionally crystallise. (19-23.)																		
3. Precipitate: Basic ceric nitrate.		4. Solution: Convert to oxalates and then to double Mg nitrates. Fractionally crystallise. (5-8.)					19. Bromates of Gd, Tb, Dy, Ho (Y). Convert to nitrates and fractionally crystallise. (16, 17.)		20. Bromates of Tb, Dy, Ho (Y). Convert to ethyl sulphates and fractionally crystallise. (28-30.)		21. Er and (Y) bromates. Convert to nitrates and partially decomp. by heat. (33, 34.)		22. Er, (Y), Sc bromates. Convert to nitrates as for 21. (35, 36.)		23. Yb, Tm, Lu and Hf bromates. Cont. fract. cryst. (37-39.)										
5. (La), Pr as double nitrates. Convert to double $\text{NH}_4$ nitrates and fractionally crystallise. (9, 10.)		6. Nd, Pr as double nitrates. Convert to Mn nitrates and fractionally crystallise. (11, 12.)		7. Crude Nd nitrate. Continue fractionating. (12.)		8. Sa, Eu and Gd double nitrate and simple nitrates of Tb, Dy, Ho and (Y). Convert to Bi-Mg nitrates and fractions from $\text{HNO}_3$ . (13-16.)		16. Gd, Tb and Dy nitrates. Convert to double Ni nitrates and fractionally crystallise. (18, 24.)		17. From 15. Tb, Dy and Ho, etc. nitrates. Convert to ethyl sulphates (20)		33. (Y) nitrate.		34. Er and (Y) nitrates.		35. (Y) and Er nitrates.		36. Er nitrate.		37. Tm bromate.		38. Yb bromate.		39. Bromates of Yb, Lu, and Hf continue fractionating. (40-42.)	
9. La- $\text{NH}_4$ nitrate		10. Pr and (La) double $\text{NH}_4$ nitrates		11. Pr-Mn nitrate. Convert to the double $\text{NH}_4$ salt and precipitate with $\text{C}_2\text{H}_3\text{O}_4$ . (11a.)		12. Nd as triple Mn-Mg nitrate, precipitate with $\text{C}_2\text{H}_3\text{O}_4$ . (12a.)		13. Sm-Mg nitrate		14. Eu-Mg nitrate		15. Gd, Tb, (Y), etc., as Mg nitrates. Convert to simple nitrates. (17.)		40. Yb and Lu bromates.		41. Lu bromate.		42. Hf bromate.		28. From 20. Tb and Dy ethyl-sulphates. Convert to simple nitrates and fract. decompose by heat.		29. From 20. Dy ethyl sulphate.		30. From 20. Ho and (Y) ethyl sulphates. Convert to nitrates and fract. decompose by heat.	
11a. Pr oxalate.				12a. Nd oxalate.				18. From 16-Gd-Ni nitrate. (43.)				24. From 16-Tb, Dy, Gd double Ni nitrates. Convert to simple nitrates. (43.)				43. Mix 18 and 24 and crystallise with $\text{Bi}(\text{NO}_3)_3$ . (25-27.)									
26. Gd and Tb nitrates with Bi.				25. Tb-Bi nitrate.				27. Dy and Tb nitrate with Bi.																	

same time, research was conducted by Barnebey<sup>18</sup> on the substitution for nitric acid of solvents such as acetone and alcohol, which gave rapid separation of cerium and didymia in the first and last fractions. Marsh<sup>19</sup> has examined the hydrated rare earth nitrates, and finds that from Ce to Dy the hexahydrates are obtained, whilst from Eu to Lu the elements form pentahydrates; several lower hydrates were also found. Of the ternary system, Ce group nitrates— $\text{H}_2\text{O}$ — $\text{HNO}_3$ , Quill and Robey<sup>20</sup> agreed that the solubilities of the nitrates do not increase with increasing atomic number, the order of decreasing solubility being Ce, Pr (La), Nd, Sm, the position of La being anomalously low, whilst in all cases the solubility is appreciably less in nitric acid solutions, of which the temperature and concentration determine the order and rapidity of separation of (La), Nd and Sm.

(iv) *As Double Nitrates.*—The salts most generally employed for this method are those of  $\text{NH}_4$  Mg, Bi, Ni and Mn. The double nitrates with  $\text{NH}_4$  and Mg are usually crystallised from  $\text{HNO}_3$  as in the preceding section, and as the result of his investigations on this subject, Welsbach patented<sup>21</sup> the application of this method to the separation of La from didymia, and to the division of the latter into its constituents, neo-, and praseo-, didymium. Solubility curves for the double nitrates have been prepared,<sup>22</sup> the authors of which employ the double Ce salts to assist in the separation of the Pr compound. The use of the Bi salt was first

advocated by Urbain and Lacombe,<sup>23</sup> who employed it as "l'élément séparateur" in the separation of "two salts A and C by means of a foreign salt B, which is isomorphous with A and C. The solubility of the B (bismuth) salt is intermediary between those of the A and C nitrates, and fractionation of the mixture gives several consecutive fractions, the least soluble of which consists of AB free of C, and the most soluble CB free of A. From these fractions B is eliminated by normal analytical procedures, such as precipitation as the sulphide by  $\text{H}_2\text{S}$ ." The process has been successfully employed for the separation of Sm and Eu; Sm and Gd; Gd and Tb; Gd, Tb and Dy. The double Ni and Mn salts  $2\text{R}(\text{NO}_3)_2 \cdot 3(\text{MnNi})(\text{NO}_3)_2 \cdot 24\text{H}_2\text{O}$  have been used for the separation of Eu and Tb from Gd; and of Nd and Pr from each other, whilst with the Mn double salt, fractionation of La and Sm from  $\text{HNO}_3$  solution is both comparatively rapid and efficient.

(v) *As Bromates.*—For the separation of the elements of the yttrium group, James employs this method to a large extent (v.s.) and according to him and his co-workers<sup>14</sup> the solubilities of the bromates in water is given in increasing sequence as Sm, Eu, Gd, Tb, Dy, Ho (Y), Er, Tm and Yb. The author has employed this method for several separations, and once the technique has been acquired, has found, like Kremers and Balke,<sup>24</sup> that it effects a rapid and efficient concentration of dysprosium and holmium in a mixture of the yttria earths. Harris and Wylie<sup>16</sup> specifically recommend this method for the rapid separation of Er or of Nd and Sm from a mixture of the yttria earth group earths.

(vi) *As Ethyl-Sulphates*.—When obtained in this form, the yttrium earths are comparatively easily separable; their solubilities in water are analogous to those of the corresponding nitrates, but owing to the ease of hydrolysis of ethylsulphuric acid, no free acid may be present. Although generally an efficient method, Kremers and his colleagues could not separate Ho and Dy by this means, but Urbain, however, recommended the use of the ethyl sulphate process in preference to the  $K_2SO_4$  method for the separation of the earths in the cerium, terbium, and yttrium groups.

(vii) *As Acetyl-acetonates*.—In combination with the use of non-aqueous solvents, these compounds, as  $R[CH(COOCH_3)_2]_3$ , have been employed with some success both for specific isolations and more general separations. Data is, however, lacking, and it is presumably upon this account that the method is falling into disuse.

(viii) *As Picrates*.—Provided the absence of Ce and Th is assured, crystallisation of the rare earth picrates forms a ready means of producing separate concentration of the didymium and Ho-Er groups; for the separation of Er from the yttria groups, however, this method is neither as applicable nor as rapid as other processes.

In general, the present trend of research upon crystallisation of the rare earth elements follows that of "spot-testing" reagents. Fractional crystallisation of organic complexes is being investigated to a certain extent,<sup>25</sup> but it would appear that more attention is being paid to precipitation processes rather than to crystallisation methods. Of the more recent suggestions, that of Kleinberg<sup>26</sup> utilising sulphamic acid appears to be attracting some attention, but although the originator of the method claims results comparable with those obtained by the alkali double sulphate separation of yttria and lanthania sub-groups, the process has had insufficient general usage for unqualified commendation.

## 2. Methods of Fractional Precipitation

Precipitation methods are based generally upon the individual differences in basicity of the rare earths, the order of which, commencing with the least basic, is Ce<sup>IV</sup>, Yb, Tm, Er, Ho, Tb, Sm, Gd, Nd, Pr, Ce<sup>III</sup>.<sup>27</sup> To utilise the slight differences between the individual members and to remove occluded impurities, it is necessary to repeat the precipitation several times. The number of operations required for the precipitation processes is not, however, usually as great as that for separation by crystallisation, consequently precipitation methods are normally employed for initial separations, crystallisation processes being reserved for purification purposes.

The rare earth elements may be precipitated as hydroxide salts or organic complexes. There is also included in this section fractional thermal decomposition of the nitrates.

(i) *Precipitation as Hydroxides or Basic Salts*.—This is generally effected by gradual addition of  $NH_4OH$ ,  $MgO$ ,  $CuO$ , etc., to the rare earth solution, the precipitate obtained containing those compounds less basic than the precipitant, whilst the solution retains those elements more electropositive. Just after the last war, Prandtl and Rauchenberger presented the results of

research on separation of the rare earths by precipitation as hydroxides, etc.,<sup>29</sup> and, *inter alia*, found that the solubility of the basic salts separated was greatly affected by the presence in solution of such salts as the chlorides or nitrates of  $NH_3$ , Mg, Cd, Zn, etc. Temperature also played an important part, and for separation in nitrate solutions, the addition of cadmium nitrate much simplified the process. Studies of the precipitation processes have been carried out by Bowles and Partridge,<sup>27</sup> who, using NaOH solution, recommended that fractional precipitation of the earths might be carried out by careful regulation of the pH.

A recent process for the extraction of Ce<sup>28</sup> involves precipitation as the basic sulphate of this element and its associates, followed by hydrolysis by 2%  $NH_4Cl$  in weakly acid solution which leaves the quadrivalent cerium as hydroxide whilst impurities go into solution. The process may be carried out, using NaCl instead of the ammonium salt, but in this case separation is not complete.

An additional point worthy of note is that the oxides of the rare earths may themselves be employed as the precipitating agents.

(ii) *Precipitation as Salts of Inorganic Acids*.—Several methods have been devised, some of which have stood the test of time, whilst others have "passed . . . in the night." Of the former class, the following have been probably the most successful:—

(a) *As Chromates*.—The precipitates obtained with  $Cr_2O_3$  were thoroughly investigated at the beginning of the present century,<sup>30</sup> when it was found that cerium is precipitated from solution as a basic dichromate and after removal by filtration, Pr, Nd and Sm may be obtained with La, from the filtrate as neutral chromates by agitating the boiling solution with a current of steam. The cerium earths do not yield as well to this method as do those of the yttria group, which are separated in the order Tb, Yb, Er, Gd. Yttrium is easily separated from Tb and Gd thus, and generally the process serves for the initial separation of a mixture of which the individual constituents may be easily purified by other more specific means.

(b) *As Sulphites*.—The addition of a saturated solution of sodium sulphite to neutral or faintly acid solutions of the rare earths containing thorium, precipitates the cerium and yttrium earths leaving thorium in solution; with the acid sulphite in the cold, however, the reverse is the case. The method has been mainly employed, therefore, for initial separations, or where thorium is the element it is desired to isolate. Gaseous  $SO_2$  has been employed, and with basic salts in suspension is useful for the separation of Nd and Pr; owing to the lengthened period of time required for this separation, however, more use is made of the solid salts than the gas.

(c) *As Thiosulphates*.—This is another method more frequently employed for the removal of thorium from mixtures. The precipitate of thorium thiosulphate carries down with it a certain amount of the rare earths, but these may be removed by repeating the process or by conversion of the thiosulphates to the oxalates, which are washed with ammoniacal ammonium oxalate solution. The actual composition of the thorium precipitate is a matter of doubt, according to Mellor<sup>31a</sup>

<sup>27</sup> Marsh, *J. Chem. Soc.*, 554, 1939; Young, Arch and Shyne, *J. Am. Chem. Soc.*, **63**, 957, 1941.

<sup>28</sup> *Ind. Eng. Chem. (Anal.)*, **11**, 368, 1939.

<sup>29</sup> Bowles and Partridge, *ibid.*, **9**, 124, 1937.

<sup>30</sup> Brit. Pat. 25238/39.

<sup>31</sup> *Z. Anorg. Chem.*, **120**, 120, 1921; **122**, 311, 1922.

<sup>32</sup> Muthmann and Bohm, *Ber.*, **33**, 42, 1900; *Z. Angew. Chem.*, **15**, 372, 1282, 1902.

<sup>31</sup> "Comprehensive Treatise on Inorganic and Theoretical Chemistry," 1924.

(a) Vol. X, chap. 57, § 38, p. 550; (b) Vol. V, chap. 38, § 6, p. 563.

thorium thiosulphate has not been prepared, but as that author also states<sup>31b</sup> that thorium thiosulphate is precipitated, the position is rather ambiguous. No doubt the precipitate is the basic thiosulphate, as the tendency of the rare earths to form basic salts would no doubt find a counterpart in the associated thorium.

(d) *As Fluorides*.—In the absence of Th, the use of HF or its alkali normal, or acid, salts has given good results for the removal of Zr and Ti. These elements form double fluorides after precipitation and fusion with KHF, and as such are soluble in water whilst the rare earths remain as insoluble fluorides. The solubility of the rare earth fluorides in a large excess of acid is dependent upon the basicity of the element. For separation of the cerium and yttrium groups use is made of the reactions of the fluosilicates, thus in cold mineral acid the cerium fluosilicates are hydrolysed to the fluorides, whilst with the yttrium elements this is not so as they are held in solution by the mineral acid.

(e) *As Carbonates*.—In dilute solution, the alkali carbonates precipitate the rare earth elements as the simple carbonates  $R^{III}(CO_3)_3$ ; in concentrated solution, however, it is the double carbonate which is precipitated; the potassium salts are those generally prepared, by virtue of their greater insolubility. Of the rare earths, the potassium double carbonates of the cerium group are the least soluble, whilst the yttrium group compounds are rather more soluble. The thorium double salt is, however, more soluble than any of the rare earths. In large amounts of water, the cerium group compounds are decomposed and precipitated as simple carbonates in the sequence (La), Pr, Ce, Nd; the yttrium compounds and thorium remain stable, however, and this fact has been utilised as a method of separation of the Ce and Y groups. Barium carbonate precipitates Th and the cerium elements, but not the members of the yttrium group.

(f) *As Ferrocyanides*.— $K_4Fe(CN)_6$  precipitates elements of both cerium and yttrium groups as well as thorium, but by fractional precipitation from a neutral solution, it is possible to concentrate Er in the primary fraction in an almost pure state. The ferrocyanides have the general formula  $R^I R^{III}[Fe(CN)_6]_nH_2O$  (where  $R^I = Na$  or  $K$ , and  $R^{III} =$  rare earth elements), and are so poorly soluble that double decomposition is an easy method of separation. Basic salts of the type  $R^{III}(OH).(R^{III}Fe(CN)_6)_2$  are obtained by neutralisation of hydroferrocyanic acid with hydroxides of the rare earths,<sup>32</sup> they are poorly soluble in water and dilute acids, and are decomposed by concentrated acids.

Precipitation of the rare earths by potassium cobalticyanide was advocated by Bonardi and James in 1918, as a most rapid method for the removal of yttrium from its earths, but the author has been unable to find reference to any further work substantiating either the method or the claim.

(g) *By Means of Hypophosphates*.—This method was widely employed for the complete separation of thorium from the rare earths as they occur associated in monazite. The sodium salt is normally employed, but the solution must be in acids other than sulphuric, otherwise insoluble double sulphates of the rare earths are formed which precipitate with the thorium hypophosphate. To avoid this, therefore, hypophosphoric acid is prepared in the solution by oxidation of yellow phosphorus, or by anodic oxidation of  $CuP_3$ .

Advantage of this method of separation is taken in a Russian patent<sup>33</sup> for the treatment of apatite. Hypophosphoric acid is assumed to be formed by interaction between the phosphorus of the mineral and the  $HNO_3$  with which it is treated. The solution is cooled to below zero and the crystalline mass obtained by filtration is dissolved in a small amount of hot water, from which solution rare earth phosphates separate in crystalline flakes.

(h) *As Sulphates, Nitrates or Chlorides*.—These salts lend themselves more to processes of crystallisation than precipitation. The basic sulphates and nitrates are applicable only to the purification of already separated salts of the cerium earths. The chlorides and oxychlorides form but a mediocre method of concentration and separation, although in 1933 a patent was taken out<sup>34</sup> in which a solution of rare earth and thorium chlorides is saturated with HCl gas at low temperatures, whereby  $ThCl_4$  remains in solution whilst the rare earth chlorides are precipitated almost completely in the hydrated form. The method would appear to be applicable to industrial processes, but for laboratory investigations the incompleteness of the separation would be a serious drawback.

(i) *Thermal Decomposition of the Nitrates*.—This method was almost universally used by the older workers,<sup>35</sup> and is based upon the fact that when heated, the nitrates of the rare earths are converted to the nitrites and oxides, the rate of transformation being directly proportional to the basicity of the element. Heating of the nitrates is carried to a predetermined point, the melt leached with the minimum amount of hot water and filtered, the more basic elements having been converted to the oxides, they are now insoluble. The filtrate is evaporated and the process repeated. This method, although giving good results in experienced hands, is unsuitable when the terbium earths are present in large amounts or when the worker has not previously employed the method. Kremers and Balke,<sup>34</sup> using the method for the separation of Ho and Y, found it necessary to add a little Sm to the melt in order to obtain a good separation.

(iii) *Precipitation as Organic Complexes*.—Under the title of organic complexes, the author groups, as well as true complexes, those salts of such acids as stearic, sebacic, etc., whose use is common in some separations of the rare earth elements. Organic reagents have provided an opening for the advancement of experiments on separation procedures. Coupling of the elements to the larger molecules available must increase to a certain extent the slight differences between the individual elements, and even the slightest alteration in properties thus produced may be seized upon to be elaborated into a clearer and cleaner method of separation. Organic acids, as such, have been employed for many years, but owing to the comparative youth of the study of the applications of organic bases to inorganic reactions, information is of a necessity far from complete or satisfactory. Progress, however, is being made, particularly by such workers as Schemjakin,<sup>36</sup> Feigl<sup>37</sup> and Schoeller,<sup>38</sup> etc.

To be continued.

33 Russ. Pat. 38, 139, 1934.

34 Brit. Pat. 395,300, 1933; Russ. Pat. 41,510, 1935.

35 Marignac, *Ann. Chim.*, **14**, 247, 1878 (5); Nilson, *Ber.*, **12**, 554, 1879.

36 *Z. Anorg. Chem.*, **217**, 272, 1934; *J. Gen. Chem. (U.S.S.R.)*, **5**, 667, 1935; *Compt. rend. acad. sci. (U.R.S.S.)*, **14**, 115, 1937; *J. Gen. Chem. (U.S.S.R.)*, **7**, 1553, 1937; *Compt. rend. acad. sci. (U.R.S.S.)*, **15**, 347, 1937; *J. Gen. Chem. (U.S.S.R.)*, **8**, 452, 1938; *ibid.*, **9**, 698, 1939.

37 *Qualitative Analyse mit Hilfe von Tüpfelreaktionen*, Leipzig, 1938.

38 "Analysis of Minerals and Ores of the Rarer Elements," London, 1940.

# British Iron and Steel

## The Development and Future of the Industry

By A Special Contributor

*Fuel, transport, and ore are likely to show much higher costs in the future. Much experimental work is necessary to make the best possible use of the lean ores available in this country, and plant and equipment must be modernised or arrears of repairs and maintenance made up as quickly as possible in the post-war period to facilitate economic production.*

NO sane man imagines he can foretell the future of the iron and steel industry with accuracy. Our best predictions remain more or less sagacious guesses. The reason for this is obvious. We may acquaint ourselves with the forces that are at work in and about the industry, but we can estimate neither their relative strengths nor their persistency under changing circumstances, and it is on these that their ultimate effect must depend. And even if we could calculate the resultant of these forces we should be faced with the insoluble problem of the influence of individuals. We tend to underestimate this factor in its relation to the iron and steel industry, yet great leaders of the industry, whether directly connected with production or research, may be as decisive of the lines of development as that of great generals is to the fate of armies in the field. This throws an impenetrable veil over the future, since all will admit that it is impossible to foretell the industry's great men or the direction of their influence. It is possible, however, to forecast to some degree the changing nature of conditions that face the industry, and by glancing over the developments of the industry, which have become its historical background, seek possible guidance towards its continued progress.

### Main Products

It is, of course, well known that iron is the chief component of the products of the iron and steel industry; in cast or wrought forms, or in the many types of steel, it is vital to modern civilisation. Indeed, its use has become so common that its importance is generally overlooked, yet no other metal has contributed so much to the welfare and comfort of mankind. Although it is true that the present decade has seen an amazing expansion in production of non-ferrous metals, particularly the light alloys of aluminium and of magnesium, that of iron still accounts for something of the order of 90% of the output of all metals. No other metal is capable of giving the wide range in physical properties that makes iron and its alloys available for an almost unlimited number of purposes, from the smallest pin to the largest of ships, for building structures, bridges, rails, motor-car bodies, and all kinds of engineering.

### Early Developments

Although apparently the art of making iron and steel reached a high standard in ancient times, few implements have survived as direct evidence to prove the antiquity of iron smelting. It is generally assumed that iron and steel were made and used between 5,000 and 6,000 years ago. It is probable that steel was made by the cementation and crucible processes, but that the methods adopted

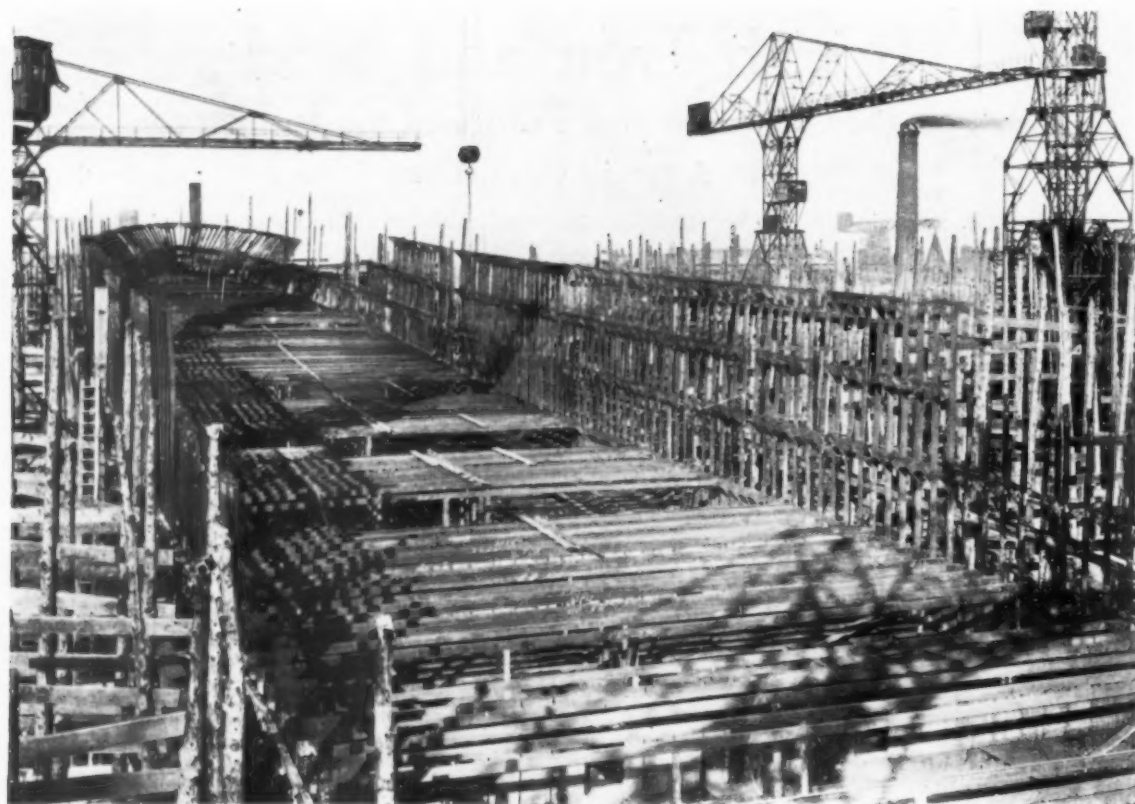
were lost to civilisation, the former to be revived in Belgium about the year 1600, and the latter rediscovered by Benjamin Huntsman in 1740. It seems likely, however, that the Wootz steel of India, the famous blades of Damascus, Syria, and the equally famous steels of Toledo, Spain, were made by one or both of these processes, although the methods would be crude compared to those adopted to-day.

Little or no progress was made in this country until about the middle of the 14th century, when iron ore was smelted and cast iron produced. Prior to this the Catalan forge was the chief instrument used in the production of iron. Shaft furnaces were in existence in this country early in the 14th century. Both forms were used to produce malleable iron, but from the time when the first shaft furnace had been found capable of producing molten iron, a steady increase took place in the size of the furnace, and particularly in the height. By 1670 there were furnaces in the Forest of Dean 40 ft. in height and from 8 ft. to 10 ft. wide at the boshes.

Until the early part of the 17th century charcoal was the fuel used for reducing or smelting the iron ores, when Dudley applied coal for this purpose. Charcoal must have remained the principal fuel, however, as it was not until well into the 18th century that coal began to be generally used, the improvements in the art of manufacturing iron, which made its use successful, being due to Abraham Darby.

About this period the effect of new mechanical developments in the textile industry was being felt. A number of notable inventions completely altered the character of industry and the daily life of great masses of people. The new machines, practically all of British origin, began the period which brought about the industrial revolution. These new machines needed a new power, and in 1766 James Watt developed a practical steam engine to drive them.

The development of Britain's vast mineral resources, checked in the previous century by lack of steam power, now proceeded apace. Darby had already discovered that iron could be smelted with coke, and the new era was ushered in by the use of Smeaton's blast-furnace in the Carron Iron Works in 1760. The method was soon improved by the use of steam and by Cort's invention, in South Wales, of puddling, in 1783, and his use of rollers instead of hammers in the making of iron bars in 1784. John Wilkinson, the first of the new ironmasters, was thought to be iron mad because he believed that iron could be used for building bridges, ships and houses, yet an iron bridge, cast by Darby, was erected over the Severn at Colebrookdale in 1779, and Wilkinson launched an iron ship on the same river in 1790. So great was the



The shipbuilding industry uses a considerable tonnage of steel. In a normal year between 400,000 and 500,000 tons are required in Britain for hull construction alone. The amount of steel for a liner of 25,000 tons gross is approximately 15,000 tons, and this illustration shows the partial construction of a large liner built by Messrs. Vickers Armstrong, Ltd.

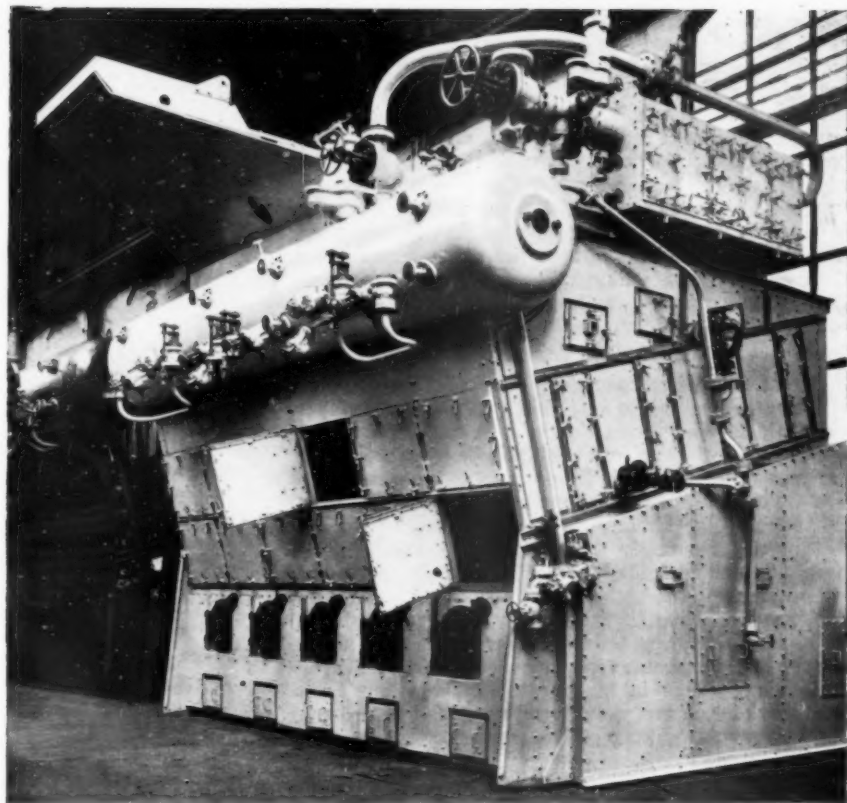
progress in the production of iron during the industrial revolution that a negligible export trade in the early years had grown to 90,000 tons in 1815.

Steel continued to be made by the cementation and crucible processes, in comparatively small quantities, for cutting tools, springs and the like, wrought and cast iron being the only materials available to the engineer for structural purposes. The wrought iron then made contained a relatively high percentage of slag, and there was a demand for an improved material. Bessemer, in 1856, sought to effect this improvement by experiments designed to remove the impurities from molten pig iron, using air as an oxidising agent. His early attempts proved abortive as the ingots produced were full of blowholes. In an effort to eliminate the blowholes, spiegeleisen, containing 20% manganese, proved successful, but, as the spiegeleisen contained carbon, some carbon was added to the iron, and so Bessemer unintentionally recarburised his iron and produced steel. As subsequently developed by Bessemer, the process of converting molten pig iron into steel required the use of hæmatite pig iron for its success, and was unsuitable for the majority of British ores. However, efforts to adapt the Bessemer process to phosphoric iron smelted from domestic ores were successful when Thomas and Gilchrist developed the basic Bessemer process in 1877.

The great demand for steel following the success of the Bessemer process was phenomenal, and many other inventors sought to improve the steelmaking process in order to assist in meeting the ever-growing demands. But the only process which subsequently became a rival of the Bessemer was that developed through the invention of the regenerative principle by Siemens. In 1861, the brothers Siemens applied this principle in a furnace built at Birmingham. Designed somewhat similar to furnaces used in the puddling process, it was fired with preheated gas and air; in this furnace they melted pig iron and oxidised the carbon with iron ore to produce steel. Subsequently Martin suggested using steel scrap with the pig iron and the process became known as the Siemens-Martin or open-hearth process. As with the Bessemer process, both acid and basic furnaces were developed according to the nature of the hearth and slag, and various modifications have since been incorporated into the process.

Bessemer steel supplied the major demands for steel until about 1910, when the output of open-hearth steel gained supremacy. Great progress was made in the production of steel in this country by the open-hearth process, especially the basic type introduced in 1884; this method grew so rapidly in popularity that, ultimately, very little steel was produced by the Bessemer

A large quantity of iron and steel is used in the construction of engines and boilers used for ship propulsion. The illustration shows one of eight sets of Babcock and Wilcox boilers manufactured by Messrs. Vickers Armstrong, Ltd., for supplying steam to the turbo-electric machinery installed in the liner "Queen of Bermuda," built by Messrs. Vickers Armstrong, Ltd.



process. Some indication of this is given from the following percentages, which show the proportions of steel production by various methods during the three years 1936-8: Basic open-hearth, 74.5%; acid open-hearth, 17.5%; basic Bessemer, 3.3%; acid Bessemer, 1.9%; electric furnaces, 1.7%; side-blown converters, 1.1%.

#### Modern Methods of Production

Basically, the processes invented and developed in this country have not changed, although progress in the size and mechanisation of plant has been continuous, and, apart from the electric furnace which began to be applied early during the present century, it can be said that the world's iron and steel industry was born and cradled in Britain.

Over the many years from the initial use of shaft furnaces the general trend of production has moved away from the simple and direct production of wrought iron to the complex indirect manufacture of steel. Developments have been along three main lines: (1) Increasing the size of the furnace and developing mechanical auxiliaries to produce pig iron more economically and in greater amounts; (2) invention of various processes for changing this impure iron into more useful wrought iron or steel; (3) production of steel either by way of wrought iron or from pig iron direct. The change from the small intermittent operations controlled by highly skilled men to the large machine-driven continuous furnaces has been associated with enormous expansion in total output and as great a saving in labour and a notable conservation in raw materials.

Although great progress has been made in applying indirect methods of production, direct methods continue to be investigated. Since 1910 many methods have been proposed for making iron and steel direct from the ore, and extended experimentation on a semi-commercial scale has produced some marketable metal by these processes. Most of them rely on the fact that iron ore is reduced by gas in the upper cooler part of the blast-furnace, giving the following reaction:—



at 800° C., too low a heat to break up other minerals in the ore. Consequently, hot iron ore is passed through a revolving kiln containing producer gas, and the iron sponge formed therein is either passed direct to an electric melting furnace, or quenched rapidly to prevent reoxidation, separated from the unreduced ore and gangue, and the metallic part briquetted or melted.

Considerable progress in the making of sponge iron has been made in Sweden, where a plant has been developed and is operating on a commercial scale, but whether so-called direct processes are destined to supplant the present indirect system of smelting to an impure product and then refining it, cannot be predicted. In view of the great investment in the present plants for making steel, which is reasonably satisfactory to the user, any innovation would have to show a considerable saving in costs, or have material collateral advantages before it could be widely adopted. Such savings and advantages have not yet been fully demonstrated. In Sweden, coal is an expensive raw material, and economies effected by the use of sponge iron in that country may not be obtained elsewhere.

The main efforts towards economy in production, apart from increased size of furnaces, would seem to be careful preparation of all materials used, especially the coal which is likely to be much higher in cost than before the war, and the beneficiation of the iron ores is just as important. Much has been done in this direction because during the war production has been almost wholly from the lean ores which form the bulk of home supplies. At the outbreak of the present war a number of blast-furnaces in this country had been modernised, new coke-ovens built, and many improvements made in steel furnaces and rolling mills. Indeed, many plants compared favourably with the best practice in any country.

### Iron Ore Resources

One of the factors frequently overlooked by the users of iron and steel is the availability of the essential raw materials for the production of iron and steel in this country. Apart from iron ore, fuel, flux, air and water are just as necessary as the ore itself. At one time it was thought that the ore and fuel deposits were inexhaustible, like air and water, which are replenished as they are consumed. It is now appreciated that the supply of ore is limited, especially the richer grades; indeed, many of the best ores are already exhausted, and it is generally known that the supply of the more valuable fuels, suitable for metallurgical purposes, will, at the present rate of consumption, be exhausted in a relatively short time. It is interesting to compare the world resources of iron ore, actual and potential, in order to obtain a mental picture of the position of this country in rich ore resources.

An estimation is by no means easy, and the statistics are less reliable for the less well-known deposits, but Table I\* enumerates some of the most important resources. First magnitude deposits are those containing at least a billion tons, second magnitude deposits those with 100 millions to 1 billion tons, and third magnitude deposits those with less than 100 million tons. All these are further classified into actual and potential reserves, the former including economically available material because of their size, grade or location, and the latter including those not as yet exploitable.

Whilst Western Europe is well supplied with iron ore, the eastern part of Europe (excluding Russia) is rather poor in reserves. The Soviet Union is rich in deposits, and although the best ore is at Krivoi Rog, there are large supplies of good ore in the Urals. The United States will face a serious situation in about ten or fifteen years as a result of the depletion of high-grade Lake Superior reserves. Possible solutions are importation of high-grade Brazilian ore, use of the large low-grade reserves if cheap methods of extraction can be developed, and increased use of eastern magnetites and other ores. The large Cuban and Wabana reserves are also possible sources of major quantities of ore; although nearer to the United States than Brazil, these ores are of lower grade and more difficult to smelt. Asia has large reserves in India and the Philippines, but China and Japan are deficient in good ores. The *per capita* consumption of iron of Asia (as a whole) is still but a small fraction of that in the United States or Western Europe. North Africa has a moderate but important reserve of good grade ore, all of which is exported. South Africa has large reserves, quite sufficient for her budding

TABLE I.—WORLD IRON ORE RESOURCES.

Country.	Actual Reserve (Millions of Tons).	Approx. Content, Fe, %.	Potential Reserve (Millions of Tons).	Approx. Content, Fe, %.
<b>NORTH AMERICA.</b>				
Canada .....	100	50	10,000	35
Cuba .....	3,000	40	12,000	—
Mexico .....	100	60	100	—
Newfoundland .....	1,250	40	2,000	40
United States .....	3,800	45	67,000	35
Total North America .....	8,250		91,100	
<b>EUROPE.</b>				
Albania .....	20	50	—	—
Czechoslovakia .....	55	40	1,000	—
France .....	4,500	35	6,000	35
Finland .....	—	—	90	35
Germany .....	800	32	2,000	30
Austria .....	200	35	200	—
Great Britain .....	3,100	30	7,000	30
Greece .....	100	50	50	45
Hungary .....	80	40	—	—
Italy .....	60	50	—	—
Norway .....	300	35	1,000	30
Poland .....	140	30	200	25
Portugal .....	50	45	100	—
Rumania .....	25	40	—	—
Spain .....	800	45	1,000	35
Sweden .....	1,250	62	1,250	60
Switzerland .....	20	30	—	—
U.S.S.R. (in Europe) .....	3,100	45	15,000	35
Yugoslavia .....	70	50	—	—
Total Europe .....	14,670		34,000	
<b>ASIA.</b>				
China .....	500	40	700	35
India .....	3,600	60	10,000	—
French Indo-China .....	50	50	—	—
Japan .....	70	40	—	—
Korea .....	70	35	300	30
Malaya .....	75	55	—	—
Netherlands E. Indies .....	100	—	1,500	—
Philippines .....	500	47	500	—
Turkey .....	15	65	35	—
U.S.S.R. (in Asia) .....	1,400	45	2,100	—
* Total Asia .....	6,340		15,700	
<b>AUSTRALIA.</b>				
Australia .....	400	60	moderate	—
New Caledonia .....	20	52	—	—
<b>SOUTH AMERICA.</b>				
Brazil .....	4,000	60	11,000	40
Chile .....	120	60	—	—
Colombia .....	—	—	35	35
Peru .....	100	60	—	—
Venezuela .....	100	60	1,000	45
Total .....	4,320		12,000	
<b>AFRICA.</b>				
Algeria .....	160	50	—	—
Tunisia .....	30	50	—	—
French Morocco .....	—	—	60	—
Spanish Morocco .....	30	55	—	—
French Guinea .....	—	—	2,500	45
Rhodesia .....	—	—	very large	25
Sierra Leone .....	20	55	—	—
Union of South Africa .....	1,000	55	7,000	45
Togo .....	—	—	20	50
Total .....	1,210		12,000	
<b>WORLD TOTAL .....</b>	<b>35,240</b>		<b>161,800</b>	

iron and steel industry; their grade and location, however, will probably preclude export in any large quantity for some time. Australia has adequate reserves for local needs.

England, it will be noted, has large reserves, but the grade is low and requirements are high, necessitating considerable importation of better grade ore. This fact, together with the knowledge that fuel costs will be high, will necessitate very careful organisation and the best use of available plant in an effort to achieve economy in production.

### Future Prospects

In the past Britain was generally recognised as being in the forefront among the producers of iron and steel in quantity and quality, but for many years her production tonnage has been surpassed by a number of countries more favourably placed. In respect of quality, however, she continues to maintain a leading position among the world's producers. In the early days the major developments of the industry were initiated and put into practice in this country—developments upon which the iron and steel industry of the world is still

(Continued on page 164)

\* World Iron-Ore Map, by H. M. Mikami. *Econ. Geol.*, 1944, 39 (1), pp. 1-24.

# Research and the Future of the British Iron and Steel Industry

By D. A. Oliver, M.Sc., F.Inst.P.

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*Research is the systematic exploration of the unknown. Systematic exploration avoids confusion, reduces the possibility of premature conclusions, indicates the often unexpected influence of one factor upon another, and results in the final application of a discovery or a development for the greatest benefit of mankind. It is this research which is the essential basis of industrial progress and which is discussed by the author in its application to the future of the iron and steel industry.*

THERE has been a praiseworthy attempt recently to direct attention in both political and business circles to the all-important fostering and extension of industrial research in this country. These efforts have been successful in securing from the Government an expression of encouragement and financial concessions in taxation which, even if not immediately applicable, foreshadow the new state of affairs which will shortly hold good. Before specifically referring to the iron and steel industry, account will be taken of what has already been achieved in the immediate past in Great Britain, and a brief comparison made with the efforts of other highly developed countries.

It is a British trait to accord the honours generously to members of other countries for outstanding scientific and technical achievements. Additional publicity in the British Press has often resulted in the people of this country getting a view out of true perspective and an impression that this country is lagging behind. In future it is hoped that when the many successes of research are more insistently publicised, a greater sense of satisfaction with the not inconsiderable British contribution will emerge. Nevertheless, most will agree it is salutary to study the shortcomings of the present-day situation as likely to indicate a better organisation for the future in which the national heritage of originality and scientific genius are given free play and widespread application.

Some enthusiasts are apt to refer to successful research and development as if it were some commodity which could be created at will or purchased with an adequate sum of money. This is only partially true, and the fostering of research is perhaps better likened to an out-of-doors horticultural experiment where, with the provision of suitable conditions as regards soil, fertiliser and adequate moisture, much can be done by intensive and systematic planning, but mental provision must always be made for the vagaries of the weather and for the quite unpredictable winds that blow.

An important point to bear in mind is the intensely human side of the origination of new ideas, new designs, and new procedures in relation to the more efficient harnessing of the material world to the needs of humanity. While ideas can be readily shared through the many media of communication, they invariably originate with individuals, and no expansion of national research activity can succeed without full recognition of the tendency of research to be an individualistic activity. This does not mean that successful team work

is out of the question, for we know that much that is successful in the modern industrial world has been brought about by the smooth and happy working of small teams of energetic workers. But it remains true, however, that if the team is promoted at the undue expense of the individual an element of paralysis is apt to creep into the organisation.

In considering the state of the iron and steel industry on the technical side, it is obviously desirable to examine the characteristics which have grown up, almost naturally, over the past 25 years. In that comparatively brief period it has been possible to see the control of processes change from almost a pure art to a scientifically founded technology based partly on applied science and partly on accumulated experience and traditional art. Hand in hand with this development, the "production witch-doctor" has yielded ground to the "works' chemist," who in process of time became "works' metallurgist," with an ever-growing staff, culminating in production control laboratories at individual works in large modern steel-producing organisations. Centralised research laboratories were then deemed necessary as the climax to the tireless study of underlying principles governing the diverse operations of the industry.

To the superficial observer science is apt to make heavy weather of what may seem simple everyday things, and thus it is not surprising that to the uninitiated research in industry often appears to be much ado about very little. There is a modicum of truth in this view, because, as processes become more precise, factors which were ignored at one time have now loomed large because the quality of the product has continued to improve. The result of all this rapid growth in attention to detail has led the more far-sighted technical leaders in the industry to be made ever more conscious that their staffs for works' control and research have become relatively too small for the great tasks which confront them, if progressive improvement in quality and lowering of production costs are to be maintained. This problem has already found a partial solution in co-operative research in industry. Moreover, this is on a scale which daily becomes more remarkable in the teeth of spirited commercial competition. It is the writer's view that still closer inter-company co-operation in the future provides one of the most promising solutions to a large number of problems which confront not only individual organisations, but different parts of the industry viewed as separate units. In the hard school of experience individual firms are daily being forced to realise that

they neither live to themselves nor die out by themselves. The economic survival of the country in world trade may even depend on the degree of success achieved in working together.

Co-operation within the iron and steel industry and with user industries need not conflict in any way with the concept of the new British Iron and Steel Research Association, under the aegis of the British Iron and Steel Federation and the chairmanship of Dr. A. McCance, F.R.S. If that new endeavour is to succeed it will focus the technical policies and problems of the industry, provide a meeting ground for internal co-operation and exchange of views, and possibly add later what will be in effect centralised research facilities for the whole industry.

### Research Abroad

Reverting to the subject of how we compare with other countries much larger than ourselves, we can say that before the war the United States, the U.S.S.R., and Germany all spent on research a greater proportion of their national income per head of population than did Great Britain. This is an intensely difficult matter on which to dogmatise, but accepting the ruling without controversy, some possible reasons for this greater activity on the part of others will now be given.

Germany was endeavouring by expanding her world trade to throw off the effects of her defeat in the first World War. To sell to others she had to offer plant, machinery and processes superior to those available to the importing countries, and in this she was broadly successful. Latterly she aimed at high internal efficiency in order to prepare for another attempt at world domination, and we know to our cost the measure of sinister progress which was made. However, real assets were also created by hard work and by the exploitation of scientific knowledge and activity. Through patents controlling new processes and a world-wide political and patent strategy, Germany pioneered vast new industries, such as those centred in aluminium, magnesium and sintered carbides, and pursued her efforts on alternative materials and methods to provide against anticipated war-time shortages. At the time these seemed almost frivolous in a world of plenty, but now they must be recognised without prejudice as contributions to applied science which we can simulate to our advantage. We must be conscious that this country took the easy and expensive route before the present war, which it will be perilous to tread again in the same carefree way, if in turn we wish to expand our own world trade on a greater scale than ever before.

In the case of the U.S.S.R. we have witnessed a remarkable social upheaval marked by a fanatical belief in the ascendancy of scientific method in both the social and material spheres. The new regime was on trial for its life to provide greater material benefits for all and to collapse a century of "normal" development into a mere ten or fifteen years. As we now know, this huge internal reordering of Russian life was further complicated by having to face the technological might of Germany on land and in the air, and the initial programme of the U.S.S.R. was so great she may well have caused the prophets of orthodoxy to shake their experienced heads. In point of fact, her technical and scientific organisation was broadly equal to the task, and there were created on apparently lavish and ambitious lines many large research institutes for rapidly

solving specific types of problems, each institute containing hundreds of workers. The fact that immature characteristics were also initially present was only to be expected, but after a very few years a flow of good scientific and technical publications had indicated the inherent vitality of the primary plan, and the Soviet contribution to science is of growing importance, and should not be minimised.

As regards British aeronautical research and development, it is interesting to note that recent recommendations have favoured the Soviet conception of an advanced research institute, on the lines of a university post-graduate school, with several readerships, but stimulated by the atmosphere of a typical industrial development department having full prototype facilities. It may prove that the iron and steel industry will need something of the same kind to supplement and round off the necessarily limited co-operative research between different firms, such as a special centre for studying the principles and practice of steel-making on a works' scale.

Dealing now with the great contribution of the United States, there is a wide difference between their outlook and our own on industrial research, although less so on purely academic work. In the industrial field, the commercial directors are so convinced that research must be maintained at high pressure, that all kinds of ideas have considerable sums of money spent on them, and much activity is expended before the value of some of them is clearly seen. Herein lies the secret of American progress: so much is tried out that some worthwhile advances are continually being made which more than reimburse the heavy research expenditures. Another feature is that closer links exist between the universities and the industrial groups, and some current industrial investigations are deliberately "fed-back" to the universities to maintain a utilitarian outlook in the strongholds of academic thought. Some may deplore this, but suitably organised it can keep professors, students and industry mutually up-to-date. The tendency is for industry to have numbers of likely problems for investigation, the necessary finance, but insufficient time for thorough scrutiny, whereas the university research staff has more leisure, possibly reduced facilities, but a live interest in worth-while programmes. Fundamentally, therefore, if a common basis of working together can be found it is likely to prove most fruitful. There is no doubt that the United States have something to teach us on these lines, if only to direct attention to the benefits that would flow from a vigorous policy of industrial endowment of university laboratories with modern equipment.

Another striking feature of industrial progressiveness in the New World is its incredible frankness and openness as regards laboratory findings. It has been found that the over-reticent attitude has applied brakes to the wheels of progress, and therefore it has been largely abolished. Any necessary safeguards are ensured by the maintenance of an efficient patent service wielded with an eye to the utmost development of the product. At present the British Patent Office system and the use made of patents by industry are under review, and it is well to remember the importance of patent policy as a factor in national progress.

It is, of course, inevitable in a large country like the United States, where new ideas are so highly prized, that some of the topics given effective publicity are "overdone" according to British standards, or are even

positively misleading. The net when drawn in contains good and bad, but assiduity in fishing ensures landing a fair proportion of good fish. Failing to fish at all merely ensures the absence of success! Let us, therefore, not fail to see that it is better to back some doubtful ideas along with the sound ones rather than to pursue an over-cautious policy of conservative sterility.

### Centres of Research

In many industrial laboratories it is evident that more workers are required who are freer from commercial "rush" and responsibility. Monastic isolation needs to be guarded against, as otherwise the stimulating atmosphere of contact with live needs and problems can prove a real loss. There is more than ever before ample scope for research workers of widely differing temperaments and capabilities, but there the guiding hand of the leader of the group is necessary to ensure overall success.

On the subject of buildings, it can be said that some firms have provided palaces, whereas others have managed with improvised simple accommodation. It normally yields an important return financially if the staff are contented and situated in attractive surroundings when problems of administration become simpler. Post-war, the quality of work undertaken and the spruceness of the research department associated with a particular organisation will doubtless grow in importance and will therefore become an economic factor to be reckoned with commercially.

### Research in Great Britain

Endeavouring now to be more specific, it can be said, broadly, that research on steels and alloys in this country is in a healthy state so far as the approach from the fundamental atomic and physical side is concerned. Starting with the discovery of the electron by Sir J. J. Thomson in 1897, and continuing with his and Lord Rutherford's brilliant studies on the atomic state, the way was open for outstandingly significant contributions by the late Sir William Bragg and his son Sir Lawrence Bragg (now Cavendish Professor at Cambridge), who really jointly initiated the first large-scale attack on the atomic architecture of matter in the solid state. A significant stage in the continuation of these studies, so far as metals and alloys are concerned, was the elucidation of the order-disorder transformations in metals by Bragg and Williams on the theoretical side and Sykes on the experimental side. Valuable experimental studies in the crystal structures of alloy systems followed by Bradley and his co-workers and Hu'me-Rothery, and outstanding theoretical studies by Mott, Jones and Wilson. Recently the structures of cementite, austenite and martensite have been elucidated, thereby laying stronger foundations for the still further building up of precise mental pictures of the fine structure of steels. There is thus every reason for satisfaction in considering the British contribution to this new and growing branch of physics and metallurgy. In electron diffraction, we have also led the field, following Sir George Thomson's brilliant initial work so ably followed up by Finch and his co-workers. The technique of the electron microscope has unfortunately not been so assiduously followed, but the recent noteworthy work in the United States by Zworykin and his colleagues has revived interest in this country, and has clearly exposed a field of work which deserves energetic development.

There is also scope for extended studies on the inter-diffusion of metal atoms, and for a vigorous extension of

many other most promising lines of work which are already fruitful on a small scale. We can therefore see that quality of achievement in limited directions must not be allowed to divert us from bringing further workers into the field in order to get quality and quantity simultaneously. So often in the past we have put the feet of others on the right road, and have had the disappointing experience of seeing them achieve objectives which were clearly within our own grasp had we had the vision and energy to go out for them with sufficient determination and boldness.

This last comment applies with particular force to our failure in the past to undertake pilot-plant development prior to running risks with the production organisations. It is rarely given to man to foresee all difficulties in scientific or technological processes, but had much of the promising laboratory work of the past been followed up by small experimental production units still under the control of the research staffs, strengthened where necessary to cope with the growing volume of work, we might well have secured the initiative in a large number of directions, where we now are licensees of industrial processes developed by other nations to which are paid not inconsiderable royalties. It is clear, therefore, that in expanding research for the British iron and steel industry clear initial recognition of the fact that we are weak in this respect will immediately suggest hopeful lines of work in many directions which could be followed up advantageously.

Quite apart from the experimental pilot-plant types of development of new processes, there is a huge field of work to be undertaken which might be broadly classed as an attempt to do what we are doing now, but by improved engineering or metallurgical technique, so that the overall cost of the operation be reduced. This type of work is broadly distasteful to a large number in British industry. If the prosperity of the iron and steel-producing and manipulating trades is to be secured and maintained in the face of fiercer competition, higher fuel costs and steadily rising wages, it will be imperative to divert a larger number of our most energetic and clear-thinking research workers to this type of comparatively large-scale production investigation.

In waging continuous war against the costs of manufacture there is obviously an economic advantage to be gained in many directions by improved instrument design and control in order to reduce fluctuations in the quality of the product, and to save man-hours to the greatest possible extent. In point of fact, more engineers and scientifically trained personnel may need to be engaged to maintain equipment which dispenses with other kinds of labour employed in the manufacturing process, and no claims for efficiency should be made which do not take into account all the factors with proper debit and credit items, which in total should show a credit balance. In the manufacture of iron and steel products, there are still certain scrap factors which from a scientific point of view must be regarded as disquieting apart from the considerable financial loss to the industries concerned. The proposal is to reduce drastically the money lost in waste by increased spending on a much smaller scale. By way of example, attempts over the last few years to exert a stricter control of slag constitution and behaviour in basic open-hearth melting have been most fruitful in lowering production costs and improving the quality of the steel being made. The degree of control at present exerted is still not so detailed

as to exclude further advances on these lines, and it is considered that when once the oxygen in the metal is under complete control immediately prior to tapping, that this factor alone, apart from anything else, will result in enormous savings to the industry. Some of the ground work necessary to impose this control has already been very capably developed under Dr. Swinden's guidance by co-operative research on the oxygen, nitrogen and hydrogen contents in solid metals, and latterly in promising attempts to extend this work so as to be effective for molten metals, such as might be drawn as spoon samples during the melting and refining operations.

The last ten years, and particularly the last five years of war-time, have witnessed remarkable strides in the application of scientific method to every phase of the iron and steel industry. This has been largely possible through the many technical committees of the Iron and Steel Institute, the British Iron and Steel Federation, and the committees set up by the Service Departments for specialised purposes. The Technical Advisory Committee of the Special and Alloy Steels Committee has functioned as a really effective meeting ground for handling a diversity of activity covering far more than mere specification work. This particular committee owed much to the dynamic energy of the late Dr. W. H. Hatfield, but it is still effective and in good hands under the present chairmanship of Dr. T. Swinden.

The network of committees already referred to enable the Universities and Government Research Departments to contribute their distinctive quota to the whole. Among the universities, Cambridge has already been mentioned in connection with fundamental studies in crystallography, but the researches of Dr. U. R. Evans and his co-workers on corrosion phenomena have assisted industry and have elucidated the principles of the underlying phenomena. The contribution of Glasgow University, under the guidance of Professor Hay, has been specially noteworthy on oxide equilibria, slag constitution and viscosity which affect not only the technology of steel-making, but also an understanding of the performance of refractories under diverse conditions of use.

Sheffield University under the guidance of Professor Andrew has conducted an important series of studies on the behaviour of hydrogen in molten and solid steel, and its influence on the incidence of hair-line cracks in alloy steels. Other universities in perhaps a less obvious way have all made their own distinct contribution. Finally, it can be said that the extensive war-time researches promoted under Government auspices will have a beneficial influence far beyond the successful solution of the actual current problem which has been undertaken.

### The Future

Looking into the immediate future, much more attention will need to be devoted to the elucidation of matters falling within the field of physical chemistry and chemical engineering, and it is in matters of this kind that a nationally based research programme with extensive facilities will show up to advantage, because the total finance will be very considerable. Refractory research at present being conducted by the British Refractories Research Association under the leadership of Mr. A. T. Green is worthy of greater support and attention post-war, particularly so far as the iron and steel industry is concerned. It is hoped that the present research

activity in the steel industry will be maintained and extended and that manufacturers of refractory products will themselves increase their own local technical controls and testing facilities.

Consideration should also be given to means of extending facilities for obtaining fundamental data on such matters as phase equilibria, whether in oxide or metal systems. This type of investigation is apt to be side-tracked on account of the time, skilled personnel and expense involved. The usual answer, which is given when such a proposal is debated, is that such types of work are ideal for training post-graduates and should be left to the universities. This would be an adequate answer if it were not for the fact that universities are not at present bound to complete any specified gaps in our knowledge, nor do they always accept detailed direction from industrial firms or committees. Undertaking heavy responsibilities with time limits are rightly designated as cramping influences, but such pleading merely admits that the primary problems are not being fully tackled. Again, a nationally financed central organisation, having a nucleus staff of experts, would seem desirable to obtain the required data rapidly. This arrangement would avoid expanding the universities unduly and would remove any motive for attempting by outside pressure to usurp their cherished liberties.

The alternative would be to bring into existence at different universities specialised staffs and laboratories to undertake a particular type of research which would be run on business-like lines, and closely linked to the professors as expert advisers. This procedure has not found favour in the past, but with suitable safeguards it offers certain attractions.

Science has undoubtedly advanced by leaving the real research worker free to select his problem and his method of solution. In industry the problem, be it easy or difficult, is more often than not chosen by circumstance, and the number of workers available in the organisation to solve it may be severely limited. In such circumstances the provision of specialised assistance, be it through research associations, universities or Government departments, becomes a matter for earnest thought by those responsible for the scientific well-being of different industries with their elaborate individual technologies, ever clamouring for assistance to advance. Perhaps the British capacity for balanced compromise is well illustrated by our present arrangements in pure and applied science, but let us frankly review what we have in the light of future likely demands. Our policy for the future is surely the strengthening of the promising efforts of the past extended and attuned to the needs for ever more originality, quality and lowered production costs. This will be better carried through as more realise that world events have thrown down the gauntlet at our feet. The challenge can be cheerfully accepted because opportunity and the distinctive genius of the British race will be brought together and will not be found wanting.

### National Physical Laboratory

It is announced that Dr. N. P. Allen has been appointed Superintendent of the Metallurgy Division of the above Laboratory. Since 1935, Dr. Allen has been senior research metallurgist in the research and development department of the Mond Nickel Co. Ltd., Wiggin Street, Birmingham.

# Some Aspects which affect the Future of the British Iron and Steel Industry

By J. Ross

(Manager, Dalzell Steel Works, Colvilles Ltd.)

*Almost every industry is dependent upon ready supplies of iron and steel in suitable forms and at economic prices. To ensure an adequate output, it is essential that Britain should have a well-organised and highly efficient iron and steel industry; to achieve this involves many problems, but steady and persistent work and the proper appreciation of the responsibilities shared by both workpeople and managements should enable the industry to meet the needs of the finishing trades, not only for the home market, but to regain and expand vital export trade. Some aspects of the problems to be solved are discussed.*

**P**EACE hath her victories no less renowned than war" might well be the slogan of British industry in the years that lie ahead; but victories are not achieved by slogans, but by wise planning and hard work, and both are essential if the problems with which industry will inevitably be faced in the post-war years are to be satisfactorily solved.

Not only did the advent of war bring into being many new industries, but it also brought a vast change in the nature of the materials produced by old-established trades. Motor-car manufacturers produce aeroplanes and tanks; small arms replace sewing machines; and "engineering rounds" become shells and guns. Consequently, the steel industry produces in large measure an entirely new type of product. Thus the first effects of war were the installation of new kinds of plant and radical alterations to existing plants, and what is perhaps more important, the virtual abandonment of our export trade. But that was not all. The war machine demands men and material AT ALL COSTS, and consequently industry has lost, and in many cases permanently lost, skilled tradesmen, technicians, and men of high administrative ability and experience. Also, to some degree, efficiency and economy have had to take second place.

In so far as the iron and steel industry is concerned, the problems which will arise during the transition period—that is, from cessation of hostilities until industry is re-established on a peace-time basis—will be most acute. To what extent, if any, the industry will be Government controlled, and with the advantages and disadvantages thereof, we are not here concerned. It may be of interest, however, to note that in America it is claimed that Government control has had the effect of reducing the productivity per man-hour.\* Be that as it may, it appears to the writer that the future, and the planning therefor, places definite responsibilities on managements and workpeople alike, and there are many aspects of the problem which must be faced jointly. It is, therefore, proposed to discuss the future of the industry along these lines.

Consideration must be given at the outset to the possible demands to be made on the steel industry, and it is estimated that in the immediate post-war years home requirements will approximate to those of the years just prior to the outbreak of the war. In addition to the needs of our home consumers, a determined effort will require to be made to recapture our export markets, which, as explained above, have been closed.

How, then, can the situation of developing the industry be faced with a view to filling our own requirements and competing effectively with those countries which, though formerly our customers, are now, through war developments, likely to be our competitors.

The first consideration from the point of view of the management should be that of plant development. During the war years, and in fact for some time before, all steel plants have been running up to maximum capacity and in many cases little time has been allowed even for ordinary maintenance, so that existing plants require a considerable and thorough examination with a view to rehabilitation and modernisation. Equally, since the start of the war, it has been imperative that some changes be made, and it is also true that there have been additions and alterations made to existing plants, but for the most part these have been arranged to meet the highly specialised needs of the moment and much of the work which has been done will be of little use in satisfying the requirements of ordinary peace conditions.

The industry is consequently confronted with the necessity of reviewing the situation in the widest possible manner, and with the maximum available information at its disposal as to likely requirements, and determining what new plant is required and what development and improvement of existing plant can be carried forward with greatest speed and efficiency.

It must be borne in mind that many countries in recent years have become steel producers, and that the plants laid down are of the most up-to-date type. It is also probable that much of the plant abroad, destroyed during the war, will eventually be replaced by the best now procurable and unless our engineers can cope with these problems, and speedily, it will mean a constantly increasing drag on the industry in the way of inefficient production and, as a corollary, high costs which, in their turn, bring only one thing—inability to compete and eventual closing down of plant.

Coincidental with the consideration of plant development in the sense of mill units, furnace design, etc., must come the fullest investigation into the question of conservation of fuel. In this connection much work has been done, but much more remains to be done. It is evident that the days of cheap fuel have gone, and more and more it is clear that the utilisation of all available heat units is a matter of paramount importance. This means continuous research in the matter of design of furnaces of all types with a view to ensuring minimum

\* See Leading Article, *Iron Age*, April 13, 1944.

fuel consumption and, further, a steady increase in the use of so-called waste heat for steam generation and other purposes. Only by the most complete and efficient use of our available fuel resources and by the running of plant under optimum conditions can the burden of increased fuel costs be carried.

Refractories, lubricants and many other commodities fall within the categories where waste must be eliminated to the fullest possible extent, and only through the constant attention to, and improvement of, plant and servicing can efficiency be achieved. There can be no doubt that in all works, wastage of materials of all kinds goes on and grave responsibilities devolve on all concerned, management and workers alike, to make the utmost effort to eliminate all such inexcusable waste.

That the vital importance of metallurgical research in the iron and steel industry is clearly recognised is shown by the recent formation of the British Iron and Steel Research Association. With the liberal financial provision which has been made by the British Iron and Steel Federation, for an expenditure up to £250,000 per annum, a considerable extension in present research activities is expected immediately the requisite personnel becomes available.

Whatever work is undertaken by the new Association, there will still remain a large volume of research to be carried out by individual managements. Plant and production problems and the development of new steels and new uses for steel are of paramount importance, and consequently there will be an increasing demand for trained metallurgists. The supply, training and status of metallurgists have recently been examined by the Council of the Iron and Steel Institute, and their carefully considered review was published by the Institute at the beginning of this year.

It still remains for managements to ensure that personnel, more highly trained, and with ever greater technical skill, should be available to deal with the requirements of the future. The training of operatives, foremen, technicians and men for higher managerial posts, is a subject which can only be touched on lightly here, but with the introduction of modern plant and with the constantly increasing demands being made by steel consumers, it is vital that a generally advancing standard of efficiency should be attained. These results can be obtained by the proper selection and training of men and the necessity for doing so must be appreciated and adequate provision made, not only to attract young men to the industry, but to ensure that new entrants are encouraged to the maximum to fit themselves for those duties which they may be called upon to carry out. The selection of trainees and subsequently their posting to specific duties must be on the basis of a carefully considered scheme, and it follows that if the right men are to be attracted, conditions of service must be such as will guarantee a standard worthy of the demands being made.

Turning to the responsibilities of labour, one is constrained to point out that many of the practices which appear to arise from war conditions must cease if the industry is to survive and progress in the future.

In the first place, the writer would deprecate the oft-quoted slogan, "Labour versus Employers." If maximum efficiency is to be achieved, obviously the situation should be "Labour plus Employers," since both are interested in only one result and that a flourishing industry. It must be abundantly clear that all concerned desire only one thing—constant employment of all

plant and personnel and a ready market for the production accruing.

When production is proceeding apace there should, and will be, an adequate return for all, but such return should be based on the contribution made. It is necessary that all employees should realise that results should be the basis on which payments be made and that due reward will certainly be forthcoming for service. Equally, without service there should be no reward. Given the necessary effort in the way of honesty of purpose and application to the job on hand, no one can doubt that suitable recognition in the matter of wages and conditions would result.

In the past there has been engendered an atmosphere of suspicion as between employees and employers, and it is most sincerely to be hoped that this can be completely broken down. If instead a real spirit of confidence, one in the other, can be created then the first and most important step towards complete co-operation will have been taken.

That this may be achieved means a contribution by both sides, on the part of management by placing in front of accredited representatives of the men the economic facts of any situation arising and dealing with questions fairly and fearlessly exactly on the merits of the case. On the side of the men there must be a realisation that only through the proper channels—namely, their established trade unions—and along clearly defined and constitutional lines should their grievances, real or imaginary, be discussed and reviewed.

There has been to date an ever-growing evidence of men deciding, against the advice of their trade union leaders and executives to take matters into their own hands in an effort to force employers to accede to demands of one kind or another. It must be realised that the only approach which can be recognised is that of duly accredited representatives, and over a long period of years it has been proved that the system of negotiation which has been built up will, if allowed to function, ably cope with all the problems which may arise.

Trade unions, on the other hand, must make a determined effort to control their members, and if the time can be reached, as seems clearly possible, when representatives of both sides may meet and take decisions, knowing that their findings will automatically be carried out without question by their members, then a great measure of success will have been secured.

Much has been said and written on the subject of joint production committees, and perhaps a passing reference to these may be made. In the opinion of the writer, such committees, if organised to deal only with the subject of increasing production and improving production methods, can do a great deal of good, and when this is their function, and it is honestly pursued by all members, beneficial results have been obtained. Where, however, such committees have developed along the line of criticising all things in general, usually in a non-constructive way, results have been unhelpful.

In the organisation of such bodies it is suggested that the remit should be simple and clearly defined—namely, "to consider production and the efficiency and increase thereof"—and also that the committees should be representative of all trades and grades. All matters outside this remit can be left to existing organisations.

It will be clear from the foregoing short review that the writer has made no attempt to deal in detail with any specific problem, but has endeavoured to focus various

(Continued on page 158)

# Labour and the Future of the Iron and Steel Industry

By John Brown

*General Secretary, the Iron and Steel Trades Confederation.*

*To achieve success in the development of the iron and steel industry co-operation between workpeople and management is essential, and this article presents the views of the workpeople. After referring to the trend towards centralised direction, to the effect of the protection policy and the need for further reorganisation and reconstruction, the author considers that the State must continue to intervene in the affairs of the industry and briefly outlines a scheme for State control. Steelworkers, he says, pin their faith to an expanding industry organised and controlled by a public corporation, or some similar form of controlling agency, imbued with the ideal of maximum service to the community rather than profits for private shareholders.*

**A**S the war approaches its concluding stages it becomes necessary to consider the problems which will confront the iron and steel industry and prepare plans to meet the post-war conditions within which the industry will have to operate.

Those of us who remember the conditions which followed the signing of the Armistice after the last great war do not look forward to a repetition of that experience, and the workpeople employed in the industry are anxious to see a well-thought-out scheme planned in advance which will avoid the mistakes made during the inter-war years.

Those mistakes had very serious consequences for the workpeople. For years unemployment never fell below 18%; in 1931-32 the percentage rose as high as 48%, and in fact the position was such that it could not have been worsened, from the standpoint of employment, by the closing down of the less efficient units of production, paradoxical as that may seem to be. We cannot contemplate without dismay the possibility of a return to such conditions.

If the post-war set-up in the iron and steel industry is left entirely to the present controllers of the industry, we need not expect any fundamental change in the form of its organisation or ownership. Those associated with the direction of the industry at present are apparently convinced that only minor changes are necessary, and that, speaking generally, the continuation of the policy of protection, which has operated since 1932, will ensure the maintenance of a reasonably efficient industry in this country which will be able to produce about 12,000,000 tons of raw steel per annum. Even that will be some improvement on the industry's position in the inter-war years, when we were contributing a smaller proportional share of the world's steel production. But it is not what is desired and is less than is possible in the expansive economy to which we must direct all our efforts in the coming years.

## Centralised Direction

Doubtless the Iron and Steel Federation will aim at a greater degree of central direction in the post-war period, with larger and more integrated units. Some obsolete plants may be scrapped and some of the less efficient closed down, but retained on a basis of care and maintenance, thus providing stand-by units that can be

brought into production quickly when demand exceeds the normal capacity during a period of boom, when even high-cost producers can enter the market and earn profits.

This line of policy would be quite consistent with the attitude of the National Committee for the Iron and Steel Industry, which was set up in mid-1932, after the Import Duties Advisory Committee had recommended "a considerable measure of reorganisation." A scheme was then produced which aimed at the consolidation of producing units, and the concentration of the industry under a central body to be called into existence to co-ordinate the activities of the approved associations that were to be formed as a basis for the reorganisation. The trend towards centralised direction has been accelerated by what has happened during the war.

## Effect of Protection Policy

There is no doubt that the policy of the Government in protecting the home market against uneconomic competition in 1932, and in concluding a number of trade agreements with a view to the lowering or stabilisation of their tariffs on British goods, had the immediate effect of improving the position of the iron and steel industry in this country and making it possible for some firms to convert losses into profits. Further, it is true that the reconstruction undertaken within the industry in the succeeding years enabled the industry to render a great national service during the war.

The Import Duties Advisory Committee, in their report of July, 1937, said:—

"The policy pursued by the State since 1932—which has had the effect of rehabilitating the British iron and steel industry and of putting it again where as a whole it had not been for a decade, on a profit-making basis—has promoted also the formation of a comprehensive organisation capable of exercising a powerful influence on the conduct of the industry, and enabled it to negotiate with its foreign competitors on equal terms. This has only been achieved by giving the industry a quasi-monopolistic position in the home market."

Such reconstruction as did take place was inspired by the possibilities of increased earning power, and as an example of the change in the earning power of the iron and steel industry under protection, we may cite the

experience of a small re-rolling plant situated near Manchester. It was established more than eighty years ago, and during the years of depression led a struggling hand-to-mouth existence. The workpeople employed in the plant were never certain of employment and experienced a gruelling time over a stretch of 14 years. Unemployment and under-employment were their experience, and, in addition, frequent attempts were made to reduce rates on the grounds that if relief could not be found the works would be compelled to close down. Eventually the plant was sold. The whole of the ordinary shares and a parcel of the preference shares were purchased for a sum of £53,000, at a period when preference dividends were in arrears. During the first five years of operation under the new ownership, the whole of the arrears of preference dividends was cleared off and the new owners received in dividends, free of income-tax, a sum of £58,000; £5,000 more than the purchase price. In addition, over this period £115,000 was placed to reserve, and in the financial year ending March 31, 1940, the profits of this small plant, after placing £25,000 to reserve, amounted to £114,000.

### Provision of Adequate Blast-furnace Plant

In the month of July, 1936, there were 196 blast-furnaces in blast in this country, 50 of which had a weekly capacity of 1,500 tons to 3,000 tons or over. 146 blast-furnaces had a weekly capacity of less than 1,500 tons, and of this number 86 had a weekly capacity of less than 1,000 tons. From this it will be seen that there is a considerable amount of leeway to be made good in the provision of adequate blast-furnace plant in this country. Considerable progress was made in reorganisation and reconstruction in a number of iron and steel plants in the years immediately prior to the outbreak of war. In Scotland, Messrs. Colville's, Ltd., spent some millions in the erection of up-to-date coke ovens, by-product recovery and gas-cleaning plant with new blast-furnaces, with every facility for the supply of hot metal and gas to the steelworks. This plant is completely balanced, based on the heat units produced in making the coke and for its size and purpose is probably one of the most efficient in this country.

The new works erected by Richard Thomas and Co., Ltd., at Ebbw Vale, the United Steel Co.'s Appleby Frodingham scheme in Lincolnshire, and the new works erected by Stewart and Lloyds, Ltd., at Corby, Northamptonshire, the reconstruction and introduction of an up-to-date hot strip rolling mill and cold-reducing plant by John Summers and Sons, Ltd., at Shotton, Flintshire, was a long step forward from the old traditions. These developments showed courage and vision, and indicated the line along which the industry must travel if it is to be efficient. It will be appreciated that the provision of up-to-date plant in the post-war period is going to be an expensive business. It is estimated that to put the iron and steel industry of this country into a satisfactory state of efficiency will cost between £50,000,000 and £100,000,000.

### The Industry is a Vital Interest of the State

If the declared aims of the United Nations are achieved the world may enter on a period of free international trade when the axis nations have been defeated. The present directors of the iron and steel industry have apparently come to the conclusion that there is no future

for the iron and steel industry in this country unless behind a protective tariff wall. Whatever form a reconstructed iron and steel industry may assume, it is clear that there can be no return to the days of unregulated internal competitive production and marketing. It has been recognised since 1932 that the State has a vital interest in the industry and must continue to intervene in its affairs, if for no other reason than that of maintaining an efficient industry in the future in the interests of national security. If the Government were to withdraw completely the guarantee of protection against uneconomic competition and the industry had to face a similar measure of Continental competition to that experienced in the years of depression, we would find ourselves again in the same depressed condition as existed from 1922 to 1932.

Any further development of the industry that may take place should be adjacent to tidal waters where, with up-to-date handling apparatus, the necessary raw materials could be imported and dealt with expeditiously and cheaply, particularly if specially constructed ore carriers are employed for the purpose of importing ore and modern loading and discharging facilities provided, so that blast-furnaces can be burdened at a cost comparable to the average cost in the U.S.A. We see no prospect of the investing public providing the necessary capital, and therefore it would appear that in the immediate future we shall have to rely on the State providing a substantial amount of the capital necessary for reconstruction.

### A Scheme for State Control

If new capital is to be subscribed by the State, the Government must exercise a controlling influence in the conduct of the industry. This control can best be exercised through some form of public corporation. The State as representing the general community having accepted responsibility for the welfare of the industry, should control its destiny either as absolute owner or permanent partner. This corporation should be a public body, working solely in the interests of the community and should consist of a number of persons appointed by the President of the Board of Trade. The members should be appointed on the ground of their competence to conduct the affairs of the industry. They should hold office for a specified term of years, but should be eligible for reappointment.

The powers and functions of the corporation would be largely:—

"To exercise general supervision over the activities and policies of sectional boards; to co-ordinate their work, to keep a balance between the different sections of production; to adjust the policy of the industry as a whole to the general economic plan of the Government; to carry on any business ancillary to the production of iron and steel products, to acquire any patents, trade marks, etc., where deemed desirable and generally to do anything considered necessary for the efficient operation and adequate development of the industry, including such matters as fixing production and sales quotas and allocating raw materials, developing sales organisations for the industry, and concluding agreements with the iron and steel industries of other countries."

For each of the large divisions of the industry a sectional board should be established; each board to be

solely responsible for the production of the class of products covered, subject of course to the general policy determined by the corporation. As part of the co-ordination exercised by the central body, the sectional boards would have to conform to the general plan laid down in regard to the supplies of raw materials, allocations of orders and the marketing of the finished product, but all the internal details of production would be left, as far as possible, to the sectional board.

The marketing of the various classes of products of the industry would be co-ordinated by the central board to avoid unnecessary duplication and wasteful competition. The marketing arrangements for each class of product, however, would be under the control of the board for that section.

While the various sections, and even individual units, would conduct research on their own account, special provision would be made by the central body for the investigation of fundamental problems requiring extended research for the benefit of the industry as a whole.

The price-fixing body would be the central corporation itself in conjunction with a body representing the interests of consumers, the Minister having the power of final decision in case of dispute.

### Technical Efficiency

It is true that the standard of technical efficiency has been greatly improved in the inter-war period. Some critics of the British steel industry are inclined to lay the blame for the high operating costs obtaining in this country, as compared with operating costs in the U.S.A. and on the Continent, on the shoulders of the management and operatives.

The facts are that in our steelworks there are to be found just as efficient managers and as highly skilled

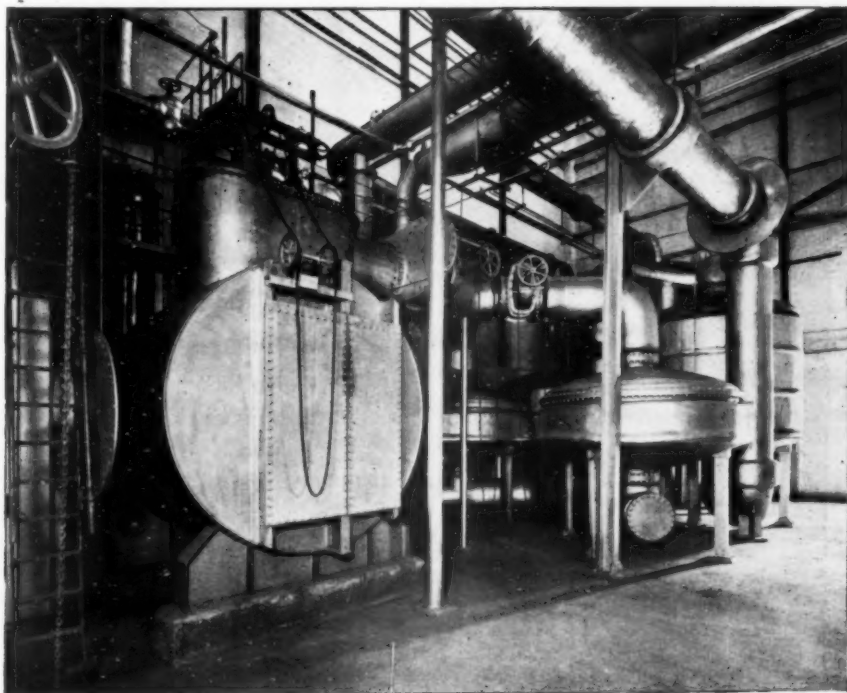
workmen as are to be found in the industry in any other country, and much of the plant will compare with the best. There does exist a considerable proportion of plant which is long out of date and should have been scrapped years ago, and the replacement of such plant by the latest up-to-date machinery will have to be regarded as an urgent matter early in the post-war period. Where up-to-date plant has been installed, as, for example, some of the most recently erected blast-furnaces, strip mills, and open-hearth furnaces, our people are producing results which are equal to the best, having regard to the raw materials at our disposal. Making allowance for the technical difficulties of operating plant under war conditions and the increased percentage of home-produced low-grade ore being worked, British iron and steel workers are to be congratulated on the excellent results they have obtained and the splendid contribution made to the war effort under conditions which have to be experienced to be understood.

### Conclusion

Steelworkers are not hidebound political theorists. They apply their commonsense to the problems that confront them. They have seen the iron and steel industry re-established and reconstructed in this country by Government assistance, direction and control. They fear unregulated private enterprise, many of them having suffered from its consequences in past years. Therefore, they ask that further steps shall be taken to perfect the machinery of direction and control within the industry, and it is their considered view that a public corporation can best serve the interests of the community and expand the output of an industry which is an essential part of our national economic system. They pin their faith to an expanding industry organised and controlled by a public

The modern contact sulphuric acid plant burning sulphur has the various vessels and pipes constructed entirely in cast iron and steel, no leadwork at all being used as in previous practice. The illustration shows typical chemical plant of this type installed by Messrs. Simon-Carves, Ltd., Cheadle Heath, Stockport.

The vessel on the left centre is the waste heat-water tube boiler, raising steam at 225 lb. per sq. in. pressure, whilst cooling the 7%  $\text{SO}_2$ /air gases produced from the combination of the sulphur. Practically all the heat given off in the various reactions of the process is utilised for the recovery of steam, and as much as 3½ lb. of steam per lb. of sulphur burned can be raised. On the right-hand side of the illustration are shown the converters, where the oxidation of the sulphur dioxide to sulphur trioxide takes place.



corporation or some similar form of controlling agency imbued with the ideal of maximum service to the community rather than profits for private shareholders. The workpeople believe that the industry can stand on its own feet if given a chance, and will be able to produce as economically and efficiently as any in the world if properly organised for the task.

We are convinced they are right in their belief and that this faith will be justified, provided the future policy of the iron and steel industry is determined by the interests of the industry as a whole and its responsibilities to the nation as a major basic service essential to the welfare and safety of the country, and not, as in the past, by considerations of the interest of this or that

group. We are satisfied that in no other way will it be possible to reconcile the contending interests within the industry and convince the users of steel products that prices are economic and not inflated.

If the iron and steel industry is to expand and progress and make its maximum contribution to the economic recovery of the world, it must be thoroughly efficient and equipped in every section with the best tools that engineering science can provide. Given such tools, the industry need fear no competitors, provided attention is given to the question of location of plant and an effort is made to organise a system of central purchasing of its raw materials and rational marketing of the finished products.

## Lower Steel Prices—A User's Viewpoint

By Sir Miles Thomas

*Vice-Chairman, The Nuffield Organisation.*

**T**HERE is a general impression firmly fixed in the minds of car manufacturers in this country that steel prices are too high and could, with advantage, be lowered so that they became more nearly competitive with those that are enjoyed by manufacturers of motor cars in other countries, notably America.

If the British motor car industry is to compete successfully on world markets, and thus provide abundant labour for British workpeople, the price of steel must be basically competitive.

War-time experiences have shown that, as a fabricating industry, the British motor manufacturing trade is equally as efficient as similar industries in other countries. In fact, British mechanics and machine tool operators are, in some cases, more productive on a "floor to floor" basis than is the case even in Detroit, given similar machine tools and tooling. This has been actually proven by time study.

Therefore, as labour costs in America are higher than they are in this country, the British motor trade would stand an excellent opportunity of competing successfully on world markets if the metal prices were in similar relationship. Tool charges and overheads would rapidly reduce as quantities increased.

Our idea of achieving lower steel prices would envisage three major factors:

1. The installation of the latest equipment.
2. The suppression of any cartel or combine system whereby those firms that are out of date and inefficient are kept alive by artificial price rigging, and
3. The British motor industry is wholly willing to co-operate with the steel industry to reduce the number of steel specifications marketed, so that longer runs, ergo, lower prices could be achieved



A pre-war view of one of the bays at the works of Morris Motors Ltd., showing the production of motor cars which consume high tonnages of iron and steel.

# The Ironfounding Industry and Co-operative Research

By Harold Hartley, D.Sc.

(Chairman of Council, British Cast Iron Research Association).

*The variety in weight, technical complexity and application of the products of the iron foundry is enormous; developments in the last two decades have greatly increased the standard of the products. It is considered that no country enjoys advantage over Britain in the art and science of ironfounding, but it is more than ever necessary that British ironfounders should manufacture products of high technical quality. This can be achieved by co-ordinated effort, and the author emphasises the value of co-operative research, which is particularly suited to British temperament, with this object in view.*

**W**HILE the ironfounding industry is closely related to the iron and steel industry, it can scarcely be said to form part of it as at present organised. The ironfounding industry derives its main raw materials, however—pig iron and coke—from the iron and steel industry, the firms in which run a number of iron foundries, some of great importance. The products of ironfounding are used in the engineering, building and other industries.

At the time of the industrial revolution, cast iron was the basic engineering material, and its use expanded with the general growth of industry in spite of the variety of alternative materials which subsequently became available. The use of cast iron extended partly because it was economic and partly because experience showed that for certain purposes the substitutes available were less suitable, although the reasons for the advantages of cast iron were only imperfectly understood. Until the first European war, the industry was conducted largely on traditional lines and was imperfectly organised. Between that war and the present one, something like a revolution has taken place, and at the same time the ironfounding industry has achieved a consciousness of itself as an entity. At the present time there are in Great Britain some 1,750 foundries, having a capacity of 2-3 million tons per annum, engaged in the manufacture of cast iron. This includes the production of white iron, grey iron, malleable cast iron and the special irons. The industry is organised in a dozen or more trade associations representing its various sections, and the majority of these are now linked through the Council of Foundry Associations, which is in a position to speak for the industry as a whole. The variety in weight, technical complexity and application of its products is enormous. Ironfounders are nevertheless united in the conduct of a process which is different from that practised in any other branch of the engineering industry, although the technical similarities between ironfounding, steelfounding and non-ferrous founding are considerable.

There are great inequalities in the size of British foundries and in the technical control exercised, but it is felt that as a result of the developments which have taken place between the two great wars, no country, Allied or enemy, enjoys advantage over this country in the art and science of ironfounding. About one-sixth of the foundries in Great Britain are responsible for producing about three-fourths of the output, but it

would be erroneous to infer from this that the existence of the small foundry is not really justified—for the manufacture of a highly specialised product a small foundry may even be preferable, and size of itself is no guarantee of efficiency.

## Development Between the Wars

The period between the wars, difficult as it seems to have been in retrospect, was characterised by two main lines of development. In the first place, continuous or mass production methods, which had proved so successful in the engineering industry, were extensively applied and resulted in more economic manufacture of standard products.

Considerable metallurgical and technical developments were effected; these resulted in a greater understanding of the complex materials employed and more effective production control. This led in its turn to the making of castings more nearly true to requirement in size and shape, of greater homogeneity and uniformity, sounder and freer from casting defects, and of a structure more suitable to meet the service requirements. These developments were by no means unrelated, because experience showed that the fullest advantage of mechanised production could only be attained with technical and metallurgical control, and, indeed, that continuous production needs technical control as a condition of its success.

## Higher Technical Quality Necessary To-day

It is now more generally recognised that to ensure a high standard of living for the people of this country it is more than ever necessary to manufacture products, of higher technical quality than are obtainable elsewhere especially since many countries overseas are developing their own primary industries. The products must embody in a high degree technical knowledge, design and skill, and their manufacture must be based on research and invention, effective management and the high intelligence and skill of the people. Dependence upon foreign inventions, the products of foreign research, can be afforded no longer, and full advantage must be taken of the available materials in the Empire, and of the quality of our scientific men and workers. Whilst the individualism of the people will prevent regimentation as a general rule, research on a co-operative basis is especially suited to the British temperament, and offers

possibilities for industrial development greater than could be attained by unco-ordinated individual effort. The ironfounding industry is confident that it has a still greater part to play in the future in the development of this country. It is self-reliant and looks forward in the post-war years to the playing of an even bigger part in national affairs than it has done during the present emergency period.

### **The British Cast Iron Research Association and Co-operative Research**

Whilst the industry has grown in corporate consciousness through development of trade associations, the work of the British Cast Iron Research Association has had a distinct influence upon its technical development. Formed, like other of the Research Associations, some 20 years ago, it is essentially co-operative. It owes its character to the fact that there is a close relation between member firms and the Association, the policy of which is governed by a Council drawn from the industry, with committees and sub-committees representing a large number of those engaged in it.

During the war the ironfounding industry has increased its support of co-operative research, and in the issue of *METALLURGIA* for June, 1943, there was published a description of the new premises which had been acquired for the British Cast Iron Research Association. To the main departments then existing—Research, Development, Intelligence (Library and Information Bureau)—the Council of the Association has recently added a Building Uses department, and has provided the director of the Association with the services of a consulting architect. The object of this department is to supply architects, builders, quantity surveyors and other inquirers with accurate information on the building uses of cast iron. It is hoped that in due course a similar department for engineering and industrial uses may be practicable.

In order to guide the work of the Association and to ensure that the results attained by its staff shall be applied to the industry without delay, there has been formed a Development Committee which is to survey broadly the whole field of the production and application of iron castings. This Committee, consisting of members engaged in the control of industrial organisations, will be especially conscious of any shortcomings of the industry. It will indicate where there is need for improvement, either in the product or in methods of manufacture, the latter as may affect both the individual worker and the operation of the plant.

This country should not countenance the continued existence of inefficient organisations, whatever their activities, and no branch of industry can afford to have members making an inferior product. Unsatisfactory and badly made goods harm the reputation of any industry and its product. For the future more consideration needs to be given to the possibility of enforcing agreed minimum standards of quality and performance to prevent the making of a shoddy article. Adoption of such a policy would bring more far-reaching benefits than generally follow from the normal activities of trade associations. All concerned in industry should participate in the support of research—both individual and co-operative, if they are able, but certainly co-operative—and for the financial outlay involved must obtain at least adequate return. The existence of the research associations offers a means of raising the

technical standard of its smallest members. It should not be difficult for such associations, given adequate financial support, to provide a pool of technicians engaged whole time in giving technical help wherever needed in the industry, thus ensuring that full advantage can be taken of new knowledge acquired as the result of research development. The research associations which are aided by the Department of Scientific and Industrial Research will play a very important part in the building up of our industries after the war; they should be all-embracing.

There is much to commend the making of a levy on all firms concerned as a means of financing research associations, and support for those who have held this view is provided by the recently published Nuffield College Report. A progressive industry should be prepared to spend 1% of its turnover on research and development, and of this one-fifth could with advantage be employed for work done on a co-operative basis. The turnover of the ironfounding industry is probably of the order of £60 million a year, and the Council of its Research Association envisages further expansion of activity after the war, based on an income of £60,000 per annum, whilst if the cost of research can be equitably spread over the whole industry, a comparatively small provision by each producer would, with a reasonable Government grant, enable the available income to reach £100,000 per annum. There is little doubt that the full application of the work of the Association would enable such a sum to be recouped easily. In the plans for the future there is envisaged a greatly extended research programme, embracing all branches of the industry and all aspects of production of the large and small firms, and of the attached and detached foundries, the former being those which are part of larger organisations. Fundamental and applied research are being done at present and both will be extended. The Association has for many years been especially conscious of the importance of ensuring that there shall be available to the industry suitably trained men to act as foundry executives, technologists, engineers and metallurgists. It has emphasised to its members the value of the technician in industry, and has helped to create a greater consciousness of the need for competent staffs. Some ten years ago it took an active part in the creation of the British Foundry School, which operated from 1935 to the outbreak of war in 1939, and there is now a very considerable demand throughout the ironfounding industry for the re-establishment of this institution.

The Research Association by its constitution provides for the co-operation of producers of raw materials of the industry, like pig iron and refined iron, metallurgical coke, moulding sands, refractory materials, blackings, etc., and for that of manufacturers of foundry equipment and plant. It is also closely concerned with methods of treatment and finishing for decorative and technical purposes, and for some years now has undertaken the research work called for by the Institute of Vitreous Enamellers.

### **Future Trends**

The future trend of the industry may be envisaged by consideration of one or two examples. It is clear that the popularity of the products which go to, and are used by, the public direct, such as the wide range of domestic goods, cookers, stoves, irons, baths and sanitary ware, will be greatly influenced by design as well as quality and finish. The competition from alternative materials

will be greater than in the past in some of these goods. The continued use of cast iron will depend more than ever on its suitability for the work and on the service it will yield, as well as on economic considerations.

In the engineering field, greater mechanical strength and a higher degree of uniformity will be needed, whilst there will be an increase in the special applications, dependant upon the capacity of the material to resist the action of heat, wear, erosion, corrosion, etc. The possibilities here are well illustrated by the development in recent years of the cast-iron crankshaft now in use in petrol and oil engines. In a new application of this type, where the engineer needs the results of direct experience to satisfy himself on the suitability of the material, it is especially important that the product offered shall conform with the required specification.

During the war many castings hitherto made in steel and non-ferrous metals, for which pressure on production has been considerable, have been satisfactorily made in cast iron—machine-tool castings, drawing and pressing dies are examples—and there should be a continuation of such use for cast iron in the future.

The industry is anticipating competition from light alloys, plastics, and welded structures, and wherever its product is the more suitable the advantages of the material will be pressed, whilst at the same time the development of competition from such newer industries will leave open to the ironfounding industry the possibility

of supplying plant and tools for the manufacture of the products. Competition from welded articles may be met in certain fields, but experience to date has led some engineers, who have tried weldings, to revert to castings on account of the greater rigidity and freedom from distortion of the material, as well as its superior damping capacity, which allow of the absorption of superimposed stresses.

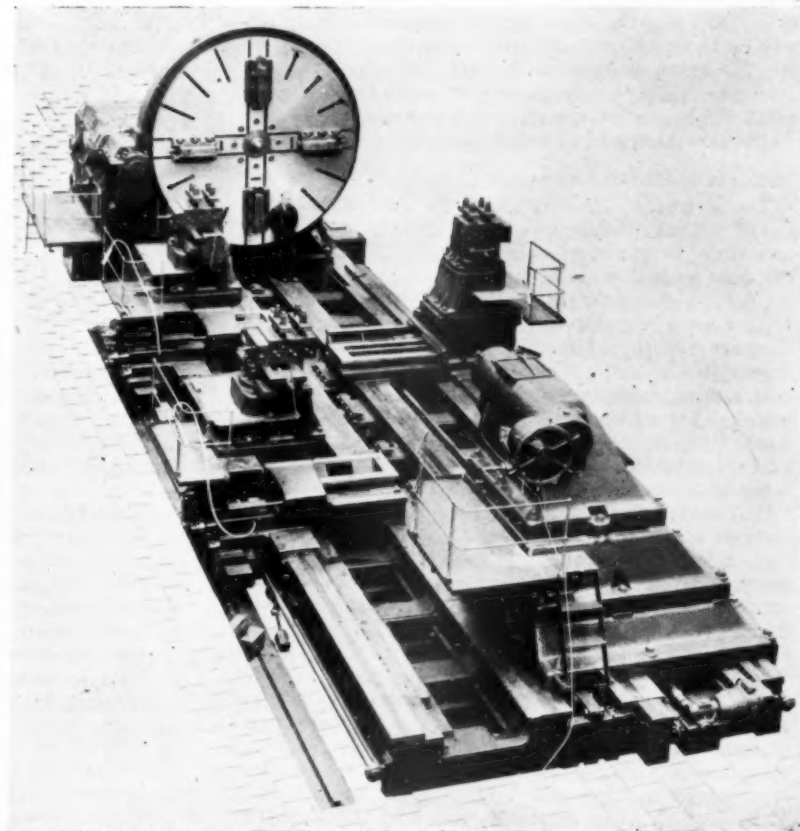
New developments in ironfounding are providing extended markets. At the present time, engineering cast irons are being made and used, with tensile strengths of the order of 35–45 tons per sq. in., and a degree of resistance to shock some three to four times as great as the best types of high-duty irons previously available. Further, there is considerable room for improvement in the foundry process itself, such as has been effected by the manufacture of cast-iron die-castings in permanent moulds, which, when attained, will make the foundry more attractive to the workers.

There is little doubt that for some years after the war the productive resources of the country will be strained to meet the demand that will be made on them. This period will provide a breathing space during which full assessment can be made of the difficulties still to be faced. This should lead to an even greater appreciation of the part to be played by research, both of a fundamental and applied character, if carried on effectively.

The machine-tool industry uses a considerable quantity of iron and steel, and although the lathe illustrated cannot be regarded as typical, because of its size, it is an excellent example of a design to cope with large work. This lathe is designed for machining turbine rotors when mounted on shafts, and is one of the largest to be produced in this country. It will swing 13 ft. 1½ in. over the saddles and admit 32 ft. 10 in. long between the centres.

The driving headstock has a large steel spindle, and the gearing, as well as the pinion and shaft, is of high-tensile heat-treated steel. The 12 ft. dia. cast-iron face-plate is fitted with four powerful steel jaws, which are adjusted by forged steel screws. The swivelling slides on the front rest carry steel tool top slides. The cast-iron bed is 56 ft. long by 14 ft. 9 in. wide. It is of the four-shear type and split longitudinally down the centre.

The net weight of the lathe without its electrical equipment is 230 tons.



Courtesy of Craven Bros. (Manchester) Ltd.

# Dehydration and Oxygen Enrichment of Blast-Furnace Air

J. B. Fortune, M.Sc., M.I.Mech.E.

*Some 60% by weight of materials entering the blast-furnace is air, and while there is much to be said for conditioning the burden charged, it seems desirable that the blast should be conditioned. As air always contains moisture which is decomposed in an endothermic reaction, the heat absorbed by the moisture content may be considerable. That the moisture content of the blast may seriously affect the operation of the furnace is generally recognised, but do the savings effected by using dried air justify the additional cost of plant involved? Efforts to improve the efficiency of the blast furnace by the enrichment of the air have been experimentally applied, and it is probable that facilities for producing cheap oxygen may provide economical means. These aspects of blast treatment are informatively discussed.*

THE references to the future of the iron trade by Mr. Arthur Dorman, in his presidential address to the Iron and Steel Institute last month, will revive interest in this country in two possible refinements in pig-iron production which have engaged the attention of blast-furnacemen for many years. Conditioning of the burden is an accepted feature of good practice: should not the blast also be conditioned? The temperature of the air entering the furnace is carefully regulated: would control of the moisture content not yield equally good results? Ores are beneficiated to reduce the idle load passed through the furnace: why not get rid of some of the inert nitrogen which accompanies the useful oxygen in the blast? Such questions have given food for thought and experiment over several generations. It is interesting to examine the attempts at blast treatment which have been made and to consider the benefits which have been said to result from such trials.

## Efforts to Control Moisture Content of Air Blast.

The weight of air blown into the blast-furnace per ton of pig iron made varies from 7,000 lb. to 11,000 lb., according to the type of practice. If the average moisture content of the atmosphere is taken as 3.5 grains per cub. ft., this means that some 48 lb. to 73 lb. of water vapour is introduced into the furnace under average climatic conditions for each ton of iron made. Though this quantity may not appear to be very great, it has been realised from very early days in the history of iron-making that variations in the moisture content have a marked effect upon operation and efficiency. Early references are found in a paper read by Dawson to a meeting of ironmasters at Bradford in 1800, and in "Papers on Iron and Steel," by Mushet in 1830. At the first meeting of the Iron and Steel Institute in 1869 the Duke of Devonshire emphasised the importance of moisture in air in furnace operation. Early attempts to control the moisture content eventually achieved some degree of practical success in 1904, when J. Gayley erected a direct refrigeration plant at the Isabella Works of the Carnegie Steel Co., the culmination of ten years of experiment. The designed capacity was 40,000 c.f.m. The refrigeration apparatus was straightforward—two 225-ton ice-making capacity ammonia compressors with the normal condensers, brine coolers, etc., served a refrigeration chamber 31 ft. × 46 ft. × 47 ft. high, heavily insulated, and containing 100,000

linear ft. of 2 in. piping. Success was immediate; details received world-wide publicity, and enthusiastically Gayley claimed a 25% increase in output and a 20% reduction in fuel consumption by reducing the moisture from the 7 grains summer average to 2 grains per cub. ft. It is noteworthy that in "Reminiscences of the First Application of Dry Blast" (Blast Furnace and Steel Plant, May, 1940) the furnace operators at Isabella thought at the time that 16% was a better figure to express the results achieved. The Isabella plant ran until 1916, and in the intervening years eleven other plants were put into operation, including the first plant in this country at Cardiff. While operating conditions varied widely, there were considerable differences in the claims made.

Plant.	(a) Tonnage Increase, %	(b) Coke Reduction, %
Isabella	25	20
Warwick (stressing "a")	26.4	13.4
" ( " "b")	12.64	18.4
Toledo	23	7.3
Cleveland Cliffs	—	10.3 (charcoal)
Hamilton	15-17	10
Dowlais (stressing "a")	26.4	13.4
" ( " "b")	9	18.4

In 1909, dry blast was at the height of its popularity, and a committee of the Franklin Institute examined the collected data and considered the following claims to be established:—

1. An approximate reduction of 15% in coke consumption and an increase of 10% in iron production.
2. Greater regularity of furnace operation.
3. Increased life of lining, up to 30%.
4. Higher blast temperatures, without sticking furnaces.
5. Reduction in the limestone consumption of 5-10%.
6. Greater regularity in silicon and sulphur in the iron produced.
7. Reduction in oncosts due to increased production.
8. Reduction in flue dust.
9. Reduction in power consumption of blowing engines due to reduced volume of refrigerated air. (The Isabella furnace showed a net saving of 10% after allowing 331 h.p. for the refrigeration plant.)

## Effect of Dry Blast on Furnace Operation.

There is no doubt that the use of dry blast did indeed show improvements in operation, but it is incorrect to attribute these solely to the control of moisture.

Gayley's change to dry blast, for example, was accompanied by a marked increase in blast temperature which contributed to the savings effected, although included in the claims made. Furthermore, no allowance was made for the improvement in ore quality indicated in his data. Despite the many advantages which the dry-blast operators claimed, they could not have offset the high operating costs of the refrigerating process, and all plants were eventually discarded. Alternative methods of dehydration were continually under review, and in 1927 the Wishaw Works of the Glasgow Iron and Steel Co. erected a plant to operate on silica gel as the dehydrating agent. The results published were more modest than the earlier claims:—

Increased output .....	9.5
Fuel reduction .....	5-45

A further tonnage increase of 7.5% was deducted as being not directly due to the use of dry blast.

Some confirmation of these figures was obtained by the British Iron and Steel Federation from tests conducted over several months, which showed that an increase in moisture from 3 to 5 grains per cub. ft. increased the coke consumption by 5-6%.

In view of the variable claims made by the advocates of dry blast, a committee of the British Iron and Steel Federation in 1932 assessed as accurately as possible, from theoretical considerations, the savings that should be obtained. Three hypothetical cases were calculated and it is sufficient for our present purpose to give the findings without detailing the methods of calculation.

#### BASIC DATA.

	1.	2.	3.
	Midlands.	North West.	Wales.
Output, tons iron per week .....	1,708	2,667	4,263
Coke consumption, cwt. per ton pig .....	28	24	19
Blast temperature, ° F. ....	1,200	1,500	1,350
Moisture content reduced from 3.5 to 1.5 grain per cub. ft.			

#### CALCULATED ECONOMIES.

Coke saving, cwt. per ton .....	1.51	1.02	0.92
Coke saving, % .....	5.4	4.25	4.84
Limestone saving, lb. per ton .....	22.7	15.3	13.8

The percentage increase in output is not easily calculable, but, from examination of past records, was assumed to be not less than the percentage reduction in fuel consumption. An attempt was made to evaluate the monetary savings from these reductions and by the reduction of oncosts, but any reference to these figures would be valueless under present-day conditions.

#### Modern Developments

After the abandonment of the Wishaw plant, no other full-scale plant was erected until 1939, when the Wood-

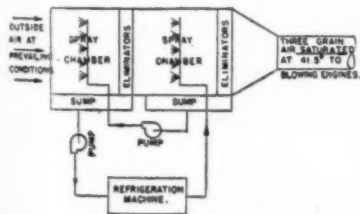


Fig. 1.—Diagram of before compression system employing direct sprays of chilled water.

adaptation of the Carrier standard refrigeration system, and was simple in the extreme, consisting of three parts only—dehumidifier, pumping plant, and refrigeration unit (Fig. 1). The "dehumidifier" consists of a

concrete structure divided into three spray chambers in series equipped with vertical perforated iron pipes through which pass iced water. The temperature of the air passing through the chambers is controlled so as to give a resultant 40° F. The centrifugal refrigerating unit operates with Karine as a refrigerant. The installation was designed to deal with the blast for one furnace only, and was said to cost \$75,000. The treated air contained 3 grains water vapour per cub. ft. Eventually two further furnaces were individually equipped with similar installations.

The impetus of war production has resulted in three other systems of refrigeration being applied to blast-furnaces in the States. First of these is the York system, made by the York Ice Machinery Corporation, York, Pa., which, like Carrier, employs a standard refrigeration layout and delivers air containing 3 grains of moisture per cub. ft. Next is the Trane regenerative system of the after-compression type, made by the Trane Co., La Crosse, Wis. (Fig. 2). The last is the Kathabar (Katherine and Barbara: names of the inventor's daughters) manufactured by the Surface Combustion Corporation, Toledo, Ohio, which controls the humidity independent of the air temperature by means of Kathene (essentially lithium chloride) as an absorption medium (Fig. 3). Both the Trane and Kathabar systems can drop the moisture to 1 grain per cub. ft.

By midsummer, 1942, the following furnaces in the States had been equipped:—

Company.	No. of Furnaces Using Dried Blast.	System.	Final Moisture, Gr. per Cub. Ft.
Woodward Iron Co., Birmingham...	3	Carrier	3
Jones & Laughlin Steel Corp. ....	Aliquippa	"	3
Jones & Laughlin Steel Corp. ....	Eliza (Pittsburgh) 1	"	3
Sloss Sheffield Steel and Iron Co., Birmingham.	2	Home made (using converted stove).	—
American Rolling Mill Co., Ashland, Kentucky.	1	Kathabar	1
Republic Steel Corp., Birmingham	1	York	3
Republic Steel Corp., Gasden....	1	Kathabar	1
Bethlehem Steel Co., Sparrows Point, Maryland.	4	Carrier	3
Globe Iron Co., Jackson, Ohio....	1	Trane	3 (installed) 2 (actual)
Inland Steel Co., Chicago .....	1	"	1
Wheeling Steel Co., Portsmouth, Ohio.	1	"	1

During the last two years further plants have been, and are being, erected. How do the results compare with those of the earlier plants? The Aliquippa works have published the following data on their No. 1 furnace operation in 1941. This furnace has a hearth diameter of 28 ft. 6 in., height 90 ft., a bosh of 18 ft. diameter, and 18 tuyeres. Operation was noticeably smoother and more uniform than with the other four furnaces not equipped with air conditioning. To demonstrate the difference in performance with and without conditioned air, a month's trial was conducted. For the first half of the month the conditioned air was transferred from No. 1 to No. 3 furnace, and then reversed for the latter half of the period. The immediate response of the furnace is illustrated in the graph of performance for that month (Fig. 4). No. 1 furnace dropped production by 14.5% and No. 3 increased by 13.9%. During the humid months of June to September production was up by 16.07% over the corresponding period of the previous year. Coke showed an average decrease of 4.26%. With the poor results obtained during the winter months, the annual increase in production was estimated at 8%, with a fuel saving of 4%.

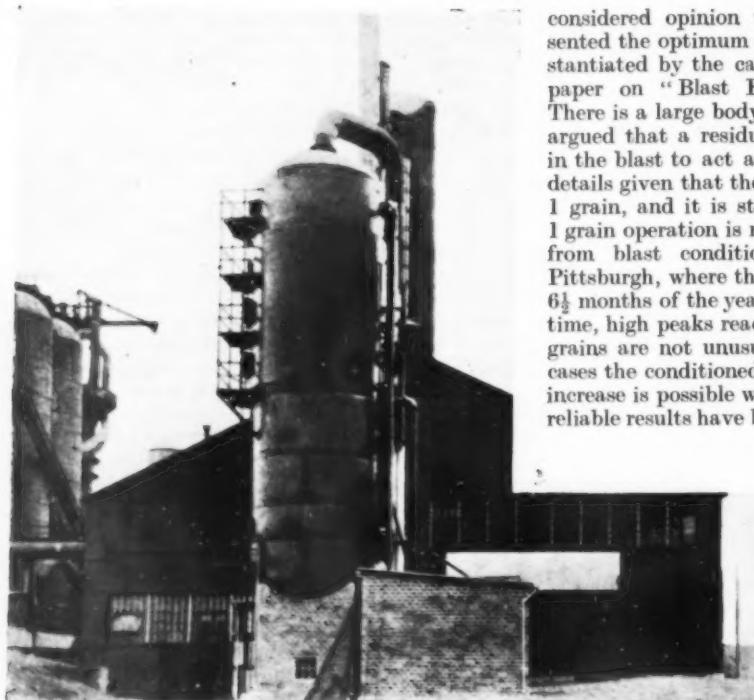


Fig. 2.—One-grain operation: The conditioning tower and equipment house at the Portsmouth plant of Wheeling Steel Corporation. This equipment deals with 50,000 cub. ft. per min. of blast at 15-17 lb. pressure. One-grain air is maintained at temperatures above freezing.

#### Optimum Degree of Dryness

It is to be noted that the Aliquippa results were obtained with 3-grain blast. Much difference of opinion exists on the desired final moisture content. At Wishaw it was found that when the moisture fell below 1 grain the burden had to be reduced to avoid cold iron and the

considered opinion then was that 1.0 to 1.5 grains represented the optimum value. The figure of 1.5 grains was substantiated by the calculations of Evans and Bailey in their paper on "Blast Furnace Data and Their Correlation." There is a large body of opinion against bone-dry air. It is argued that a residual amount of hydrogen must be present in the blast to act as a catalyst. It will be noted from the details given that the majority of plants are now operating on 1 grain, and it is strongly contended in some quarters that 1 grain operation is necessary to obtain the maximum benefit from blast conditioning, especially in districts such as Pittsburgh, where the moisture content of the atmosphere for 6½ months of the year averages only 2.8 grains. At the same time, high peaks reach 9½ grains, while daily averages of 8½ grains are not unusual during the summer months. In such cases the conditioned air protagonists claim that 12% tonnage increase is possible with 1 grain operation. Actually, very few reliable results have been made available on 1 grain operation.

#### Assessment of Results

What is the latest consensus of American opinion on dry blast? After three years of operating experience on about a score of furnaces, this was the view expressed by the chairman of the A.I.S.E. Development Committee in January, 1943:—

"Blast conditioning, concerning which several glowing reports have been made, continues to be more or less an enigma. A considerable number of installations have been made, with reported results at considerable variance. Some operators

state that they cannot tell the difference whether the blast-conditioning system is operating or not. Others refuse to promise any increase in production as a result of blast conditioning. In fact, some data has been presented to the effect that operation is actually benefited by adding moisture to the blast.

Thus we find a possible improvement stymied by a lack of concrete, authentic information. Granted that accurate determination of such results presents an involved, long-range problem, the industry needs the answer, and will be indebted to the individual or company finding it."

Twelve months later, Mr. W. H. Burr, the same authority, reports on 1943 as follows:—

"Blast conditioning continues to be a disputed topic. Fourteen conditioning units have been installed, being variously used on the suction or discharge of the blower and operating with chemical absorption or refrigeration. Reports range from no apparent gains, through a 5% gain in production, to more optimistic figures. The majority of operators seem to believe that uniformity of moisture in the blast is of greater moment than a low moisture content. In one plant, tests, in which

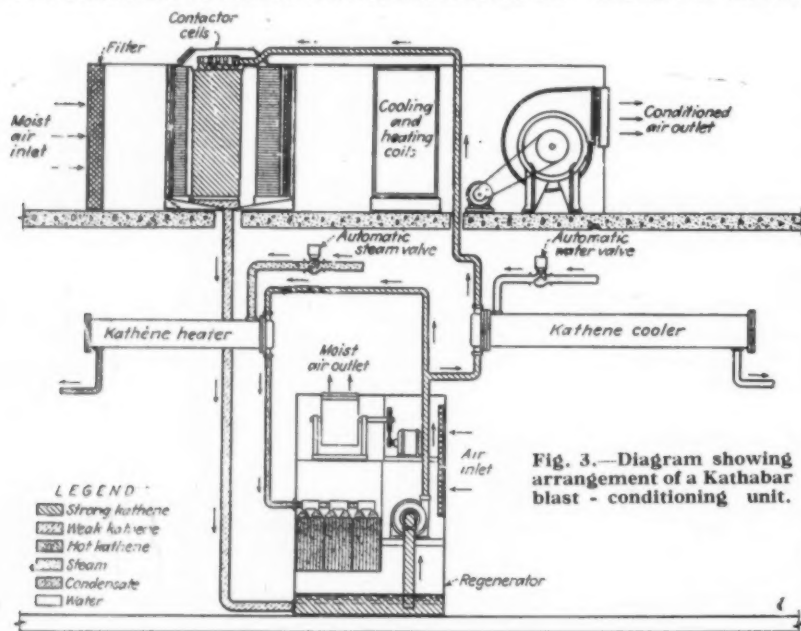


Fig. 3.—Diagram showing arrangement of a Kathabar blast-conditioning unit.

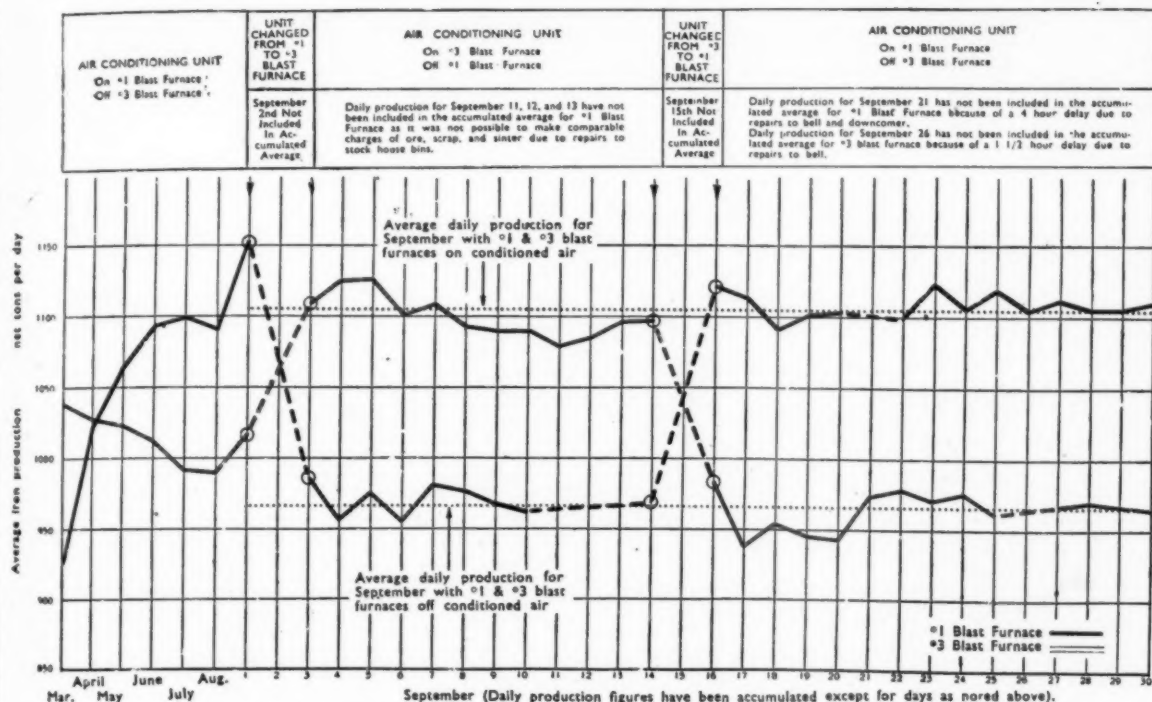


Fig. 4.—Extent that blast-furnace iron is increased by air-conditioning equipment when deducting total scrap charged from iron production.

moisture was held constant at about the maximum natural atmospheric moisture content by the addition of steam to the blast, indicated a more uniform analysis of iron with respect to silicon. Unfortunately, the lining of the furnace upon which these tests were made was deteriorated to such an extent that figures on production and coke consumption were of little value."

It would appear from the evidence to hand that a definite assessment of results cannot yet be made. Further accounts of reliable statistics are required from the operating plants before we can essay an answer to our question, "Is dried blast worth while?"

In the writer's opinion, the benefits likely to be obtained will be at a minimum at those plants where practice is already at a high level of efficiency due to the improvement in operation which has resulted from intensive preparation of the burden both by ore grading and beneficiation, by coke sizing and improved uniform quality, by limestone crushing and screening, and by blast volume and temperature control, together with correctly designed lines and distribution. He is also of the opinion that there is more to be gained from the adoption of these features than by drying the blast where adverse conditions still obtain.

#### Oxygen-enriched Blast

The oxygen enrichment of blast air obviously presents more formidable difficulties than in the case of dehydration. The full-scale plant essential for practical demonstration of calculated economies entails a degree of expenditure not willingly embarked upon by commercial undertakings. Theoretical estimates on the project were published by several investigators as early as thirty odd years ago, but there is apt to be a wide

discrepancy between calculated and realisable economies, and as yet very few large-scale trials have been made.

First in the field was the Ougree-Marihay Co. of Belgium. In 1913, Trasenster outlined to the Iron and Steel Institute the trials that his company proposed to make; but shortly after these were begun, the war intervened and the plant was occupied by the Germans. Some degree of success seems to have been achieved, but no full account of the trials was ever published although German writers made several references to them. It appears that an increase in output of 12% with a coke reduction of 2.5 to 3.0% resulted from enrichment up to 23% oxygen.

Twenty years elapsed before the next trials were made; in this case by the Gutehoffnungshütte at Oberhausen. Following upon developments in the Linde process, the oxygen company—Gesellschaft für Linde's Eismaschinen A.G.—co-operated with G.H.H. in erecting an experimental furnace which worked for 260 days in 1932 and again for two months in 1933. The lines of this furnace are given in Fig. 5. The two rows of tuyeres in the lower part of the shaft were used to introduce preheated blast-furnace gas when producing special slags of high basicity, and when the furnace was inclined to hang. The furnace was lined with carbon blocks in the hearth and ordinary firebrick in bosh and stack. For these tests, oxygen of 45% concentration was mixed with the air before the cold-blast inlet to the stoves. Representative operating data are given in Table I.

The normal capacity of the furnace was 70 tons per day on Thomas iron, and 50 tons per day on hæmatite, the normal coke consumptions being about 134 lb. higher for hæmatite, and 448 lb. higher for ferromanganese than those of the larger furnaces of G.H.H.

TABLE I. OPERATING RESULTS WITH ORDINARY AND ENRICHED BLAST

No.	No. and Duration of Test.	IA 5 Days.	IB 5 Days.	IIA 5 Days.	IIb 5 Days.	IIc 5 Days.	IIIA 7 Days.
1	Type of iron	Thomas iron		Hematite 2% Si			Hematite 3% Si
2	Oxygen in blast, %	21.0	26.3	21.0	24.1	26.0	21.0
3	No. of charges and iron production/day	90; 64.7 tons	91; 72.5 tons	65; 43.8 tons	68; 52.0 tons	69; 53.4 tons	58; 36.4 tons
4	Coke and coke carbon, lb./ton pig	2238 2008	1924 1741	2363 2130	2093 1896	1990 1803	2542 2303
5	Blast and top temps., ° F.	1467 750	1438 504	1368 687	1418 496	1339 401	1400 766
6	Pig iron analysis—						
	Si	0.67	0.72	1.9	2.07	2.1	3.13
	Mn	2.07	1.29	1.3	0.68	0.86	0.64
	P	2.19	2.11	—	—	—	0.015
	S	0.10	0.088	0.020	0.018	0.012	—
	C	3.08	3.02	4.16	4.11; G.C. 3.86	4.21	3.92; G.C. 3.86
7	Burden	80.6% Sinter 19.4% Kiruna	46.8% Sinter 51.2% Grangesberg	38.5% Menas Rubio 61.5% L.K.A.	40.3% Menas Rubio 59.7% L.K.A.	42.8% Menas Rubio 57.2% L.K.A.	39.9% Menas Rubio 60.1% L.K.A.
8	Slag, lb./ton pig analysis—						
	SiO <sub>2</sub>	1588	1400	1061	1063	1027	1102
	CaO	32.2	29.7	29.0	33.94	33.4	34.3
	MgO	41.2	44.4	45.0	50.45	50.0	50.2
	Al <sub>2</sub> O <sub>3</sub>	4.63	5.43	4.8	2.67	3.1	3.2
	Mn	13.1	12.23	14.3	9.16	8.5	7.7
	Fe	2.27	1.56	0.36	0.32	0.37	0.24
	S	—	1.22	1.2	1.65	1.82	2.1
9	Hot metal temp., ° F.	2599	2604	2475	2468	2525	2455
10	Top gas analysis—						
	CO <sub>2</sub>	5.1	8.0	6.6	9.8	11.0	7.2
	CO	33.8	38.7	32.9	35.5	36.7	32.5
	O <sub>2</sub>	0.08	0.2	0.05	0.0	0.1	0.1
	CH <sub>4</sub>	0.05	0.05	0.05	0.05	0.05	0.05
	H <sub>2</sub>	1.8	1.5	1.4	1.9	1.02	1.50
	N <sub>2</sub>	59.17	51.6	59.0	52.75	50.63	58.65
	Net C.V. B.Th U./cub. ft.	121	137	117	127	130	116
	Vol./ton pig, cub. ft.	152,000	111,000	157,000	126,000	113,000	174,000
11	Blast vol./ton pig, cub. ft. 80% O <sub>2</sub> addition, cub. ft.	114,000 —	77,500 6,950	118,000 —	87,500 4,600	77,300 6,560	129,000 —

\* I and IV measured with platinum thermocouple, II and III with optical pyrometer.

The object of the tests was to reduce the coke consumption and the high top-gas temperature. On Thomas iron, enrichment to 26% oxygen resulted in a coke saving of about 14% with a reduction of 250° F.

in the top-gas temperature, while the output increased by 12%. It will be noted that there was a reduction in the slag volume which, if allowed for, would reduce the coke saving to about 10%.

The results on hematite may be summarised as follows (Table II):—

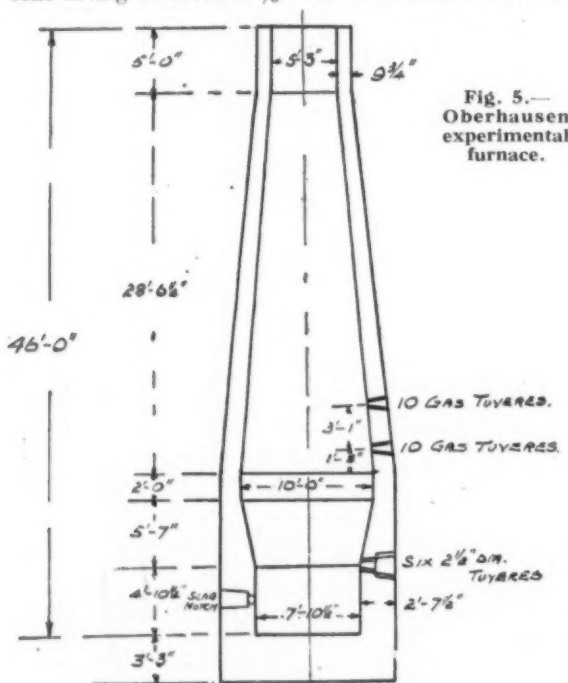
TABLE II.

	21% O <sub>2</sub>	24% O <sub>2</sub>	26% O <sub>2</sub>
2% Si Hematite:—			
Coke per ton pig, lb.	2,363	2,093	1,990
% coke saving	—	11.4	15.8
Top-gas temperature, ° F.	687	496	401
% increase in output	—	18.7	21.9
3% Si Hematite:—			
Coke per ton pig, lb.	2,542	2,292	2,306
% coke saving	—	9.8	9.2
Top-gas temperature, ° F.	766	599	535
% increase in output	—	32.6	3.0

The observed coke reduction and lower top temperature were somewhat less than theory predicted. It was the opinion of the G.H.H. Co. that tests would have to be carried out on a full-size furnace in order to determine the influence of blast enrichment on full-scale operation, as compared with experimental scale, and at the same time dispel any technical doubts as to the possibility of obtaining equally good results on large furnaces.

The third series of tests (on ferro-manganese) showed that with blast heated to 1,310° F. and enriched to 30% O<sub>2</sub> content, a saving of 1,008 lb. of coke per ton was obtained. From this result it was estimated that in a full-sized furnace ferro-manganese could be produced with enriched blast with 2,685–2,910 lb. of coke per ton.

A further object of this series of tests was the reduction of the manganese content of the slags by increasing their basicity. It was found that the manganese content of



## (NORMAL SLAGS)

IIIb 5 Days.		IIIc 4 Days.		IVA 9 Days.		IVb 6 Days	
Hematite 3% Si				80% Ferro-manganese			
24.1		26.4		21.0		30.1	
69; 47.9 tons		57; 37.4 tons		53; 17.35 tons		50; 19.8 tons	
2292	2073	2306	2087	4904	4437	3916	3548
1400	599	1319	535	1382	1175	1314	784
2.96		3.1		0.51		0.51	
0.68		0.86		79.3		79.4	
—		—		0.32		0.28	
0.010		0.014		0.013		0.016	
4.04; G.C. 3.98		4.08; G.C. 3.97		6.68		5.67	
40.3% Menas Rubio 59.7% L.K.A.		44.3% Menas Rubio 55.7% L.K.A.		84.3% Poti 15.7% Sinal		79.2% Poti 20.8% Sinal	
1080		992		2072		1671	
32.25		32.42		26.60		27.1	
52.98		52.0		37.30		42.0	
2.67		3.8		1.01; BaO 3.26		1.51; BaO 3.18	
9.04		9.3		11.13		9.42	
0.42		0.31		14.1		10.6	
2.23		1.0		0.5		0.45	
1.77		2.1		1.02		1.19	
2534		2498		2696		2678	
8.7		9.6		5.70		9.00	
36.1		37.65		32.00		41.60	
0.1		0.13		0.08		0.00	
0.05		0.03		0.05		0.00	
1.6		1.53		2.60		1.90	
53.45		51.04		59.57		47.45	
128		133		117		148	
139,000		132,000		351,000		208,000	
98,200		91,700		265,000		141,000	
5,170		8,400		—		21,700	

slags of 1.8 basicity ratio, lime to silica, could be reduced without difficulty to 5%, and in lime-enriched slags to about 2%.

The use of highly basic slags obviously led to the possibility of using ores and cokes of higher sulphur content than would be permissible in normal operation. To reap the full benefits of this possibility, further tests were carried out with slag compositions approximating to that of Portland cement—i.e., with CaO values of 60-65%. Table III gives the results of these tests, from which it will be noted that the oxygen concentration used was greater than that thought to be the most economical figure for operation with normal slags.

These trials showed that the melting of the slag in the hearth offered no difficulty, and even with blast of only 24% O<sub>2</sub> content and temperature 1,472° F. slag of this composition ran quite fluidly from the furnace. On the other hand, considerable difficulty arose due to hanging as soon as the lime in the slag exceeded 60%. After numerous attempts to prevent hanging by the use of burnt lime instead of limestone, by blowing gas into the shaft, and by the use of agglomerate, the tests were discontinued until lime-ore briquettes could be made.

Further tests with the briquetted charge were successful, and showed that the previous hanging was due to too great a slag volume. As long as the quantity of cement slag per ton pig was limited to 1,570 lb., hanging did not occur and the furnace worked still more rapidly than with ordinary air blast and normal slags. Although it had been found that 24-26% O<sub>2</sub> in the blast was sufficient to keep cement slag free running, the concentration was increased to 30-33% O<sub>2</sub> to improve the working of the furnace. The coke consumption in this case was about the same as in the production of the same quantity of normal slag with ordinary air blast.

### Conclusions

All the available evidence on oxygen enrichment was reviewed in 1935 by the Air Blast Committee of the B.I.S.F., which was able to send one of its technical officers to obtain first-hand information from G.H.H. The following are some of the findings of that body:—

1. It appears to be demonstrated that the savings expected to be achieved by enrichment of the blast can be obtained in actual practice.
2. The main governing factor in commercial application is obviously the cost of production of oxygen.
3. The mechanism of the effect of blast enrichment is to increase the proportion of available heat in the hearth. It follows that the sensible heat in the bosh gases will be decreased, and that eventually a point will be reached where there is insufficient heat in the furnace gases to meet external losses and carry out furnace reactions in shaft and bosh.
4. It was calculated that this point would be reached at about 30% O<sub>2</sub>, but that the process would cease to be economic (for the production of West Coast hematite) at 27.5%.
5. Savings would be greatest in furnaces having high coke consumptions and, in particular, those running high top temperatures.
6. With the capital and operating costs foreshadowed by the Gesellschaft für Linde's Eismaschinen A.G. in 1935 it was doubtful with the savings to be effected in the manufacture of basic iron whether the capital expenditure would be justified.

TABLE III. EXPERIMENTS ON PRODUCTION OF CEMENT SLAGS.

No.	Test No.	1	2	3	4	5
1	Burden .....	Kiruna, Limestone, Sand	Lime-ore Bricks	Kiruna, Limestone, Sand	Lime-ore Bricks	Blotberg Ore, Limestone
2	Slag quantity, lb./ton pig ...	1142	1568	1680	2037	2575
3	Dry coke charge, lb./ton pig ..	2688	2912	3024	3248	3920
4	Oxygen content of blast, % ..	30.3	33.0	33.0	30.4	34.0
5	Hot blast temperature, ° F. ....	1440-1395	1485-1440	1440-1395	1440-1395	1440-1395
6	Blast pressure, lb./sq. in. ....	5.4	5.4	5.4	5.4	5.4
7	No. of charges per shift .....	34	28	29	22	Not determinable
8	Top-gas temperature, ° F. ....	662-707	527-572	527-572	527-572	392-437
9	Average slag analysis—					
	SiO <sub>2</sub> , % .....	19.0	17.5	21.0	19.5	21.2
	CaO, % .....	62.0	61.0	66.8	62.3	63.7
	CaF <sub>2</sub> , % .....	2.6	2.6	2.1	2.8	2.6
10	Pig iron analysis—					
	C, % .....	2.7	3.85	2.7	3.2	4.0
	Si, % .....	2.0-1.0	2.40	0.7	1.0-2.0	1.7
11	Top-gas analysis—					
	CO, % .....	5.8	5.0	5.7	5.0	5.0
	CO <sub>2</sub> , % .....	45.8	47.4	47.6	45.0	52.0
12	Limestone charge, lb./ton pig ..	1310	—	2078	—	2643
13	Calculated percentage indirect reduction .....	16.7	7.6	determined	determined	determined
14	Duration of test, days .....	4	4	3	2	1
15	Remarks on furnace operation	Even drive, tuyeres clean, no slag troubles.	As in Experiment I.	Safety limit for even drive.	Very slow drive leading to slugging and blocking of tuyeres.	Pronounced hanging 3 hours after changing burden followed by blocking of tuyeres.

6. In the production of haematite, the savings are naturally greater and hold more promise of economic success.
7. In the case of 80% ferro-manganese, apart from a considerable saving in coke, there is a further saving of manganese owing to the possibility of using slags of increased basicity, and reduced flue dust losses due to the lower throat temperatures.
8. The possibility of using highly basic slags enables ores and cokes of higher sulphur content to be used, but this is only possible for the production of reasonably high silicon iron, owing to the higher hearth temperatures that would obtain.
9. Furnace operation is improved with blast enrichment, and no undue wear of the lining is likely to occur.
10. No definite conclusions were made regarding the possibility of producing cement slags, due to the incomplete nature of the German trials.

### Smelting Lean Ores with Enriched Blast

In 1938 the Gutehoffnungshütte reconditioned their experimental furnace in order to examine the merits of oxygen enrichment when working on acid burdens with a lime-silica ratio of 0.7. The following results were obtained:—

*First Trials.*—100% Wasseraufinger ore containing 28% Fe, 31% SiO<sub>2</sub> and 5% CaO was smelted with ordinary air. The slag volume was 42–44 cwt., and the coke consumption 28.12 cwt. By replacing the 19.6 cwt. of limestone per ton pig by 10.8 cwt. of burnt lime, the coke was reduced to 23.86 cwt. and the output increased 16%.

When the blast was oxygenated to 24.2% the coke consumption was reduced by a further 33 lb. only, but the output went up by an additional 34%. The oxygen concentration was limited by the moisture and CO<sub>2</sub> content of the crude air.

*Second Trials.*—A prepared burden was used comprising two-thirds calcined and one-third sintered Gutmadinger ore of 24% Fe, 25% SiO<sub>2</sub> and 15% CaO. Calcined limestone was again used as a flux with a slag volume of 50 cwt.

With oxygen enrichment to 26% oxygen, the coke was cut from 30.6 cwt. to 26.08 cwt., a saving of 14.8%, while the output went up by 48%.

*Last Trials.*—Gutmadinger ore was again used, but containing 3% more Fe, and 100% sintered.

On raising the oxygen to 27%, the coke was reduced from 30.84 cwt. to 25.2 cwt.—a saving of 18%—and the output increased by 42%.

### The Russian Viewpoint

It is perhaps surprising that the Gutehoffnungshütte did not follow up their experimental work with the full-scale trials which they deemed necessary. Preliminary work of a similar nature was carried out in the U.S.S.R. in 1932. An experimental blast-furnace was built by the Nitrogen Institute at the Chernoreschensky Works in the Gorky region with a hearth diameter of 5 ft. and a volume of 847 cub. ft., which was reduced in the 1934 trials to 670 cub. ft. Cold blast was employed with oxygen concentrations varying from 30 to 60%. Both coal and peat were used as fuels. Trials were made on all grades of iron and also with the object of producing a high quality gas suitable for ammonia synthesis. While the investigations were fully described in Russian literature, it is not known that details have been pub-

lished elsewhere. The production figures were said to be far from spectacular, which was explained by the small size of the furnace, irregularity of oxygen supply, inferior quality of materials and lack of experience. Results were apparently of sufficient promise to warrant the planning of full-scale tests on the No. 4 furnace at Makejevka in 1936, but whether these were carried out is not known.

It is interesting, however, to record the possibilities which were envisaged by the Russians at that time.

### Possible Variations of the Blast-furnace Process

1. Hot blast enriched by oxygen—the least radical method of all, and that proposed for the Makejevka furnace, using existing furnace plant and stoves. Oxygen concentration usually below 30–32%.

2. Cold blast with more than 30–32% oxygen—additional heat in the shaft to be provided by blowing heated gases into the shaft. Intensive hearth cooling required; injecting water vapour into the hearth suggested.

3. Enrichment to 55–60% oxygen to give blast-furnace gas suitable for ammonia production. Hearth temperature must be reduced.

4. Radical decrease in coke consumption—cold blast, and hot reducing gas introduced into shaft.

5. Direct steel process—charge coke peripherally, so reducing carburisation.

The Russians lay great stress on the production of high-grade industrial gas so as to overcome the question of oxygen cost.

Although an effort has been made in this article to confine all figures to those actually obtained in test runs, it is perhaps worth while to mention that the Makejevka furnace was expected to have an increase in output from 1,200 tons to 1,864 tons—a 55% increase—with 32% oxygen blast, with throughput time reduced from 7½ hours to 5 hours, blast quantities remaining the same. The coke reduction was expected to be 13%. With cold oxygen enriched blast no coke economy was anticipated. In addition, it was hoped that by the use of 50% oxygen and unchanged blast volumes the smelting time could be reduced to 3 hours, so that the output would reach 2,800 tons daily.

It will readily be appreciated that these speculations were more in the realm of fancy than reality, but they indicate the vistas of possibility which stretch before the eyes of the imaginative. It is sufficient to say in conclusion that there are possibilities in the field of both blast dehydration and oxygenation to warrant experiments being conducted in this country by the Research Association which has recently been formed for the iron and steel industry.

### Some Aspects on the Iron and Steel Industry

(continued from page 144)

aspects of the case as they appeal to one actively engaged with the daily problems arising in a steel works.

The hope for the future is that with a greater understanding of one another's problems a larger measure of confidence and more and more co-operative effort from all sides, this industry, which is vital to the country and to so many of our people can, and will, achieve that standard of efficiency which will ensure for it its rightful place in the better scheme of things so earnestly desired in the post-war world.

# Metallurgical Examination of Light Alloy Cylinder Heads from German Aircraft

By the Metallography Department (under the direction of Dr. C. Wilson, Ph.D., A.R.S.M., D.I.C.) of the Research Laboratories of High Duty Alloys, Ltd.

*This report constitutes a summary of data resulting from the metallurgical examination of parts from enemy aircraft carried out at the request of the Committee on Non-Ferrous Metal Parts of Enemy Aircraft. The parts examined were three cylinder heads taken from Bramo-Fafair 323, B.M.W. 132, and B.M.W. 801 engines.*

**T**HIS report, published under arrangements made by the Ministry of Aircraft Production, contains a summary of the metallurgical data obtained by investigation of three light alloy cylinder heads from various German aircraft, as follows:—

1. Dornier 17 aircraft, Bramo-Fafair 323 engine.
2. Dornier 17 aircraft, B.M.W. 132 engine.
3. Dornier 17 aircraft, B.M.W. 801 engine.

The cylinder head from the B.M.W. 132 engine had suffered considerable damage, but the other two items were in good condition. The main features of the undamaged cylinder heads are shown in Figs. 1 and 2 (B.M.W. 801) and Fig. 3 (Bramo-Fafair).

The components had clearly been manufactured as castings, with the rocker-box castings and inlet and exhaust connections as integral parts. The main parting line of the moulding boxes had run transversely across the fins and rocker boxes. The fins were close pitched in each case and details of the two undamaged com-

ponents are given in Table I. The manifold connections and rocker-box studs were attached to the castings by means of screw threads, but the valve stem bushes and valve seatings had apparently been shrunk into position.

The general appearance of the castings was good, and no obvious evidence of porosity or drawing was seen on the undamaged samples. In spite of the close spacing of the fins, no signs of "failure to make" were observed in any part of the casting examined.

	TABLE I. B.M.W. 801 Engine from Dornier 217.		Bramo-Fafair 323 Engine.	
	Inches.	Mm.	Inches.	Mm.
Fin spacing at tip . . . .	0.12	3.0	0.20	5.0
Fin thickness root . . . .	0.10	2.5	0.10	2.5
Fin thickness tip . . . . .	0.08	2.0	0.08	2.0
Fin depth (max.) . . . . .	1.40	35.6	1.38	35.0

## Chemical Composition

The results of chemical analyses are given in Table II. It is interesting to note that the castings had been

Fig. 1.—Half cylinder head, B.M.W. 801A engine, showing rocker box and appearance of fins.



Fig. 2.—Half cylinder head, B.M.W. 801A engine, showing manifold connections.





Fig. 3.—Cylinder head from Bramo Fafnir 323 engine.

manufactured in three entirely different alloys. The cylinder head of the B.M.W. 132 engine had been produced in an alloy of unusual composition, but in the case of the B.M.W. 801 engine, the manufacturers had found it necessary, for some reason, to use an alloy of the Hydronalium type, in which the important alloying element consists of magnesium. The Bramo-Fafnir casting had been produced in a material resembling Y-alloy.

Engine Type	Cu, %	Ni, %	Mg, %	Fe, %	Si, %	Ti, %	Mn, %
B.M.W. 132 from DO 17	10-10	—	0-27	0-96	0-11	0-04	0-02
B.M.W. 801 from DO 217	—	—	1-88	0-37	1-27	0-11	0-13
Bramo-Fafnir 323	4-12	2-03	1-19	0-24	0-27	0-12	0-02

### Mechanical Tests

The mechanical properties of the components have been assessed by means of tensometer test-pieces from selected positions. The test positions were chosen with the object of determining the effect of the operating temperatures on the properties of the material. The material forming the rocker boxes usually suffers only

TABLE III.  
POSITIONS OF TEST-PIECES.

Position 1	Rocker box.
Position 2	Centre of crown.
Position 3	Adjacent to manifold connection.
Position 4	Wall of cylinder head.

TABLE IV.  
MECHANICAL TEST RESULTS.

Engine Type	Position	Yield-point Tons/Sq. In. <sup>2</sup>	Ultimate Tensile Strength, Tons/Sq. In. <sup>2</sup>	Elongation % on 4/A.
B.M.W. 801 from Dornier 217R	1	7-1	10-2	3-0
	2	6-9	7-9	2-0
	3	5-7	8-1	2-5
	4	7-0	8-8	2-5
Bramo-Fafnir 323	1	—	9-6	1-5
	2	—	7-9	1-0
	3	—	8-9	1-0
	4	—	7-9	1-5

\* Approximates to 0-2% proof stress.



Fig. 4.—Macrostructure in section of B.M.W. 132 cylinder head.

slight deterioration, and the mechanical properties obtained at this position may be used as a basis for comparison. The positions of the test-pieces are described in Table III and Table IV contains the test results obtained on two of the components.

A Brinell hardness survey has also been undertaken on complete sections from the two cylinder heads on which mechanical test results are quoted. Typical hardness values are quoted below.

	TABLE V. HARDNESS VALUES ON SECTIONS THROUGH CYLINDER HEADS.	
	B.M.W. 801 Cylinder Head (from DO. 217R).	Bramo-Fafnir 323 Cylinder Head.
Centre of crown	58-0	49-7
Wall adjacent to cylinder	58-0	59-0
Wall of rocker box	61-5	73-0

It was noted that in the case of the B.M.W. 801 cylinder head only slight variations in hardness existed throughout the section examined.

### Macrostructure

The general structure of the castings has been observed in etched sections passing through a rocker box, valve guide and adjacent wall. The three samples examined varied greatly, as regards general quality and condition. The B.M.W. 132 casting (Fig. 4) showed unusually coarse grain size, and the etched sections were characterised

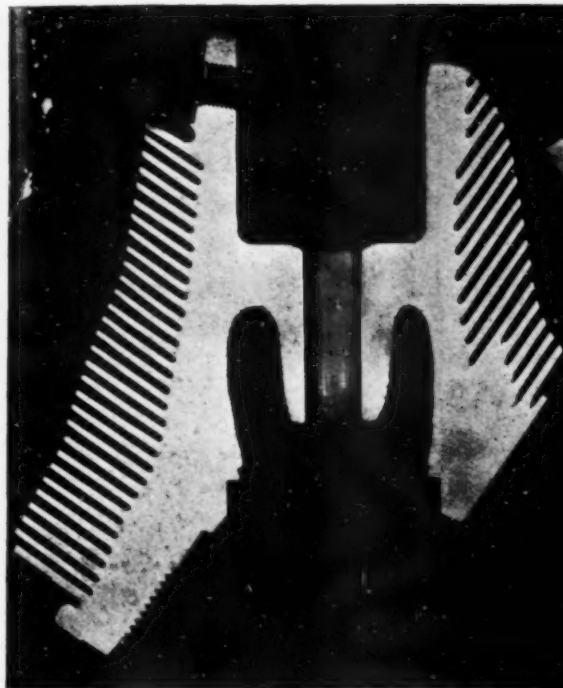


Fig. 5.—Macrostructure in section of B.M.W. 801A cylinder head.



Fig. 6.—Macrostructure in section of Bramo-Fafnir 323 cylinder head.

by the long columnar crystals extending from the inner surface. The material was also seen to be severely affected by gas porosity in the external areas of the wall. The inner zone of columnar crystals, although slightly porous, was not seriously affected by this defect and it would seem that precautions had been taken during casting to obtain improved soundness adjacent to the inside surface of the cylinder head. The casting from the B.M.W. 801 engine showed a marked contrast as regards grain size, which was seen to be fine and uniform in character throughout the section (Fig. 5). An obvious feature in this sample was the occurrence of fine shrinkage cavities in the wall section, but apparently complete soundness in the fins. The section was carefully examined, but at no position was evidence observed of visible shrinkage cracks. The section of the cylinder head from the Bramo-Fafnir engine showed considerable variations in grain size, varying from finely crystalline at the centre of the crown to a coarse crystal structure in the wall. The most striking feature of the casting, however, was the occurrence of severe porosity throughout each section examined. One of the sections is illustrated in Fig. 6. The porosity extended to the fins, many of which contained severe cracks.

#### Microstructure

A number of specimens from each component have been examined microscopically, and certain features seemed to be common to the three samples. The general particle size of the visible constituents was relatively coarse, thus providing further evidence that the components had been produced as sand castings. The photomicrographs (Figs. 7, 8 and 9) show typical fields of the microstructure. In the case of the cylinder head

from the B.M.W. 132 engine, the constituent network seemed to be abnormally coarse. The casting from the B.M.W. 801 engine showed a more favourable structure, in which the visible constituents consisted mainly of the magnesium-silicon compound, together with a complex aluminium-iron-silicon compound, but the soluble magnesium-aluminium compound was not seen in the as-polished condition. The network of visible constituents in the Bramo-Fafnir cylinder head casting seemed to be characteristic of the type of alloy.

In the case of the B.M.W. 132 and Bramo-Fafnir components, porosity of a fairly severe character was observed in almost every field examined, except in specimens prepared near the inner wall. In these areas it would seem that the porosity had been controlled to a large extent, probably by the use of drastic chilling methods. The casting from the B.M.W. 801 engine also showed a similar contrast in soundness between areas near the inner wall and areas at the centre of the wall, but generally the casting seemed to have been manufactured to a much higher standard of quality. The material at the external surface, including the fins, was seen to be reasonably sound.

#### Comments

The samples examined had clearly been manufactured as castings and the features seen in the microstructure and macrostructure provided fairly conclusive evidence that sand moulds had been employed. The junction of the two halves of the sand mould occurred along a line through the rocker boxes, normal to the fins, and it would appear that the castings had been fed by risers at the

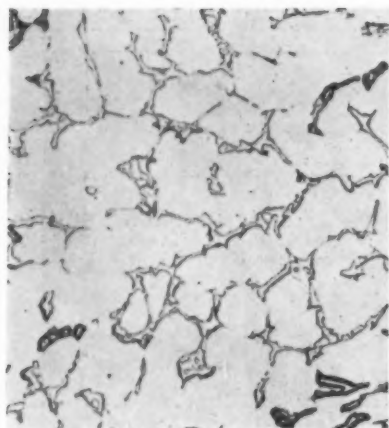


Fig. 7.—Microstructure in specimen from B.M.W. 132 cylinder head.  $\times 100$ .



Fig. 8.—Microstructure in specimen from B.M.W. 801A cylinder head.  $\times 200$ .

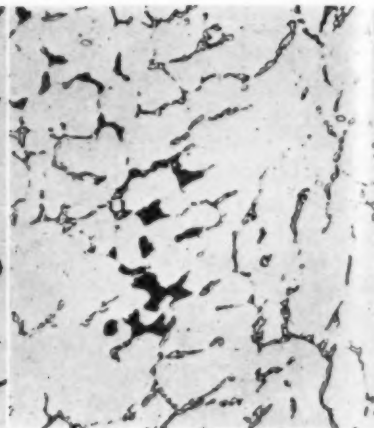


Fig. 9.—Microstructure in specimen from Bramo-Fafnir 323 cylinder head.  $\times 100$ .

open end. An interesting feature of these castings was the close fin spacing, of which details are given in Table I.

The samples from the B.M.W. 132 engine and from the Bramo-Fafnir engine would not be regarded as good quality castings, but neither sample showed evidence of any tendency to failure in service, and the components seem to have been sufficiently sound for the duty required. The casting from the B.M.W. 801 engine showed a higher degree of soundness, but would not conform with the highest standards of quality.

The three samples examined have supplied insufficient data fully to assess the standards adopted, but it would seem that the German manufacturers do not aim at high

general quality, and only insist on soundness in those parts of the component where freedom from porosity is essential. It is interesting to note also that an improved standard of quality seems to have been necessary for the cylinder head of the later engine.

The alloys used for the B.M.W. cylinder head castings are also interesting. The early casting 132 had been manufactured in a material corresponding to the American 122 alloy, which has found application in automobile pistons, but which has no counterpart in British aero-engine manufacture. The B.M.W. casting of later manufacture (801) consisted of an alloy of the Hydro-nalium type, which would not normally be regarded as suitable for applications involving elevated temperatures.

## The things you can do with Economisers

THE general idea is that an economiser is solely for the purpose of making use of the heat remaining in boiler-flue gases for feed-water heating. That is, of course, its main function and if it never did anything else an economiser would rank as one of the most important pieces of fuel-saving apparatus available to steam users.

But ingenuity and even common-sense will find other jobs for an economiser which will go a long way in saving fuel. Did you realise, for instance, that an economiser can be used for extracting waste heat from gases other than from steam boilers? And has it occurred to you that many economisers which have been condemned for operation at the pressures for which they were installed may easily be put back into valuable fuel-saving service with a little reorganisation?

The unorthodox use of economisers, a very fruitful field for investigation, is the subject of a new bulletin from the Fuel Efficiency Committee of the Ministry of Fuel and Power. It is a really excellent piece of work that factory management will enjoy reading and with considerable profit to themselves.

The bulletin begins by telling readers what an orthodox economiser is and what it does. This part alone is well worth study by those who are a bit foggy on the subject, because the function and scope of the apparatus are so clearly explained. But the most interesting part is a group of examples, most of which are of unorthodox uses of economisers.

The first example gives the cure for water-hammer in economisers, due to high feed temperature, and the second describes the way to cure condensation due to cold feed water. The next example tells of a works with six boilers, where, as a result of a great economy drive, the steam demand was so reduced that three boilers could carry the load. The economiser was now far too large for the smaller amount of feed-water passed through it. How the three banks of the economiser were separated and given three separate jobs to do is an example of the commonsense approach to fuel economy.

Two more examples describe the manner in which condemned economisers can be given a new lease of life and put to work again in reducing fuel consumption. While yet another tells how an old economiser was converted into an air-heater for drying rooms. The next item reminds us that some kilns and furnaces, as well as boiler plant, lend themselves admirably to the application of an economiser. Another section provides an answer to the problem of the feed pump, which will not handle water above a certain temperature.

The economiser examples are well illustrated by diagrams, and at the end of the bulletin is a quick-reference summary of economiser points.

The bulletin is a really valuable addition to fuel efficiency literature, and we strongly suggest that readers get into touch with their Regional Fuel Efficiency Committee for copies. It is Fuel Efficiency Bulletin No. 30.

# Spar Flanges and other Extrusions in Various Enemy Aircraft

By The Staff of Metallurgy Division, Royal Aircraft Establishment

*Data obtained as a result of a metallurgical examination of spar flanges and other extruded sections taken from enemy aircraft are summarised. The work has been carried out at the request of the Committee on Non-Ferrous Metal Parts of Enemy Aircraft.*

THE materials of a number of spar flanges and other extrusions from a variety of enemy aircraft have been examined from time to time. The chemical compositions and tensile properties of a selection of the items examined are briefly reviewed.

Details of the parts discussed are given in Tables I and II. The chemical compositions are given in Table I, and the results of tensile tests, including limit of proportionality and proof-stress values are shown in Table II. The appearance of an etched section from each item is shown one-third full size in Fig. 1. As shown in Table I, 15 German and one Japanese samples have been completely analysed. All the German materials were of the Duralumin type, and with one exception compositions lay within the following limits:—

Copper	3.90 to 4.62%
Silicon	0.21 " 0.79%
Manganese	1.01 " 1.29%
Magnesium	0.95 " 1.35%
Iron	0.28 " 0.53%
Titanium	Trace " 0.02%
Zinc	Nil " 0.20%

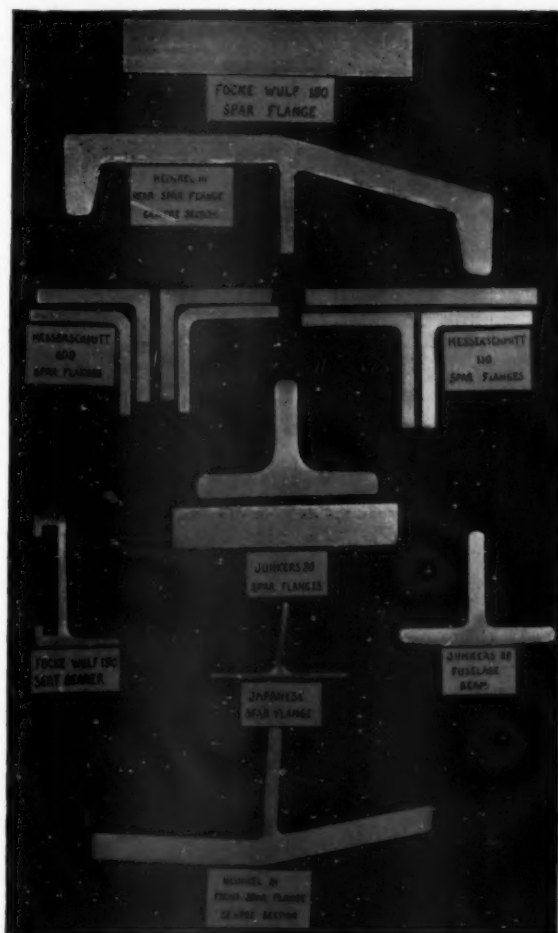


Fig. 1.—The appearance of each etched specimen examined.  $\times \frac{1}{3}$ .

TABLE I.  
CHEMICAL COMPOSITION OF SPAR FLANGE MATERIALS, ETC., FROM VARIOUS ENEMY AIRCRAFT.

Mark.	Description.	Composition, %.								
		Cu.	Si.	Mn.	Mg.	Fe.	Ti.	Zn.	Ni.	Al.
15C	Centre section spars, Heinkel 111H									
15D	Front spar, top flange	4.28	0.43	1.95	1.08	0.53	0.02	Nil	Nil	Rem.
15A	bottom flange	4.24	—	—	—	—	—	—	—	—
15B	Rear spar, top flange	4.11	—	—	—	—	—	—	—	—
	bottom flange	3.98	—	—	—	—	—	—	—	—
9-19	Main spar flanges, Me. 109									
9-21	Inner angle section, top flange	4.05	0.21	1.14	1.29	0.28	0.012	0.02	—	Rem.
9-22	bottom flange	4.19	0.45	1.11	1.18	0.36	0.015	0.16	—	—
	Outer angle section, bottom flange	4.62	0.50	1.17	1.35	0.37	0.012	0.05	—	—
8C7L	Main spar flanges, Me. 110									
8C7A	Top flange, plain strip	4.25	0.62	1.39	1.20	0.47	0.02	—	—	Rem.
8C7L	angle section	4.19	0.57	1.07	1.11	0.45	0.02	—	—	—
8C7A	Bottom flange, plain strip	4.15	0.64	1.29	1.18	0.50	0.02	—	—	—
8C7A	angle section	4.09	0.79	1.11	1.06	0.40	0.02	—	—	—
4	Junkers 88									
0	T-section beam, fuselage	4.72	0.39	0.56	0.68	0.40	0.02	0.12	—	Rem.
1	Main spar, top flange. T-section	3.90	0.43	1.22	1.04	0.31	0.02	0.09	—	—
2	Strip	4.03	0.44	1.03	0.95	0.42	0.02	0.04	—	—
3	bottom flange. T-section	4.27	0.51	1.12	1.11	0.34	0.02	0.05	—	—
4	Strip	4.08	0.42	1.12	0.99	0.41	0.02	0.20	—	—
1	Focke Wulf 190									
7	Main spar flange	4.10	0.37	1.01	0.96	0.52	Trace	Nil	Trace	Rem.
	Seat bearer. T-section	4.25	0.57	1.21	1.14	0.45	—	—	Nil	—
	Japanese OHSF Zeke aircraft									
	Rear spar, upper flange	2.13	0.28	0.55	1.12	0.28	Trace	7.90	Nil	Rem.

The exception to this range of composition was the Junkers 88 fuselage beam (Item 4), containing 4.72% copper, 0.56% manganese, and 0.68% magnesium.

Tensile test results, including proof-stress determinations, are given for 17 German items in Table II. The values obtained on longitudinal test-pieces varied from 21 to 25.4 tons per sq. in. for 0.1% proof stress (12 values of 24 tons per sq. in. or over), 28.5 to 35.6 tons per sq. in. for maximum stress (eight values of 33 tons per sq. in. or over).

The German components are similar in composition to British material covered by

TABLE II.  
RESULTS OF TENSILE TESTS ON SPAR FLANGE MATERIALS, ETC., FROM VARIOUS ENEMY AIRCRAFT.

Mark.	Description and Reference.	L.P., Tons/ Sq. In. <sup>2</sup>	Proof Stress, Tons/Sq. In. <sup>2</sup>			Max. Stress, Tons/ Sq. In. <sup>2</sup>	Elongation, %
			0.1% <sub>0</sub>	0.2% <sub>0</sub>	0.5% <sub>0</sub>		
15C	<i>Centre section spars, Heinkel IIIH—</i> Front spar, top flange ..... (Long.) (Trans.)	14.7 14.4	24.1 20.8	24.2 21.7	24.5 22.8	33.9 30.9	12 on 2 in. 11 on 4√A
15D	Front spar, bottom flange ..... (Long.) (Trans.)	10.1 12.3	25.2 19.9	25.4 21.1	25.6 22.4	31.8 29.2	10 on 2 in. 11 on 4√A
15A	Rear spar, top flange ..... (Long.) (Trans.)	18.0 12.0	24.0 21.0	24.2 21.8	24.4 22.9	33.0 32.8	13½ on 2 in. 15 on 4√A
15B	Rear spar, bottom flange ..... (Long.) (Trans.)	13.6 12.9	22.4 19.3	22.7 20.3	23.1 21.5	28.5 28.4	10½ on 2 in. 13 on 4√A
9-19	<i>Main spar flanges, Messerschmitt 109—</i> Inner angle section, top flange ..... (Long.)	11.7	24.0	24.6	25.4	33.7	11
9-21	..... bottom flange ..... "	19.2	24.9	25.6	26.2	35.6	13
9-22	Outer angle section, bottom flange ..... "	10.0	25.0	26.0	27.4	29.2	9
SF1L SF1A SF2L SF2A	<i>Main spar flanges, Messerschmitt 110—</i> Top flange, plain strip ..... (Long.) " " angle section ..... Bottom flange, plain strip ..... " " angle section .....	15.1 15.9 18.1 18.9	24.1 25.4 22.1 23.5	24.3 26.0 22.6 23.8	24.6 26.8 23.2 24.0	31.6 35.0 31.0 32.7	12 16 12 16
4 29 21 23 24	<i>Junkers 88—</i> T-section beam, fuselage ..... (Long.) Main spar, top flange. T-section ..... " " Plain strip ..... " " bottom flange. T-section ..... " " Plain strip .....	16.9 15.2 14.7 15.2 14.5	24.1 24.8 21.0 25.4 22.1	24.6 25.0 22.0 25.8 23.1	25.1 25.5 23.1 26.2 24.3	33.6 32.2 28.5 32.2 30.6	15 10.7 16.7 10.7 18.7
11 17	<i>Focke Wulf 100—</i> Main spar flange ..... (Long.) Seat beam—T-section .....	17.2 —	25.0 —	25.1 —	25.4 —	34.4 34.8	13½ 12
<i>Japanese G8SF Zeke aircraft—</i>							
	Rear spar, upper flange—1. Web ..... (Long.) " " " " 2. Web ..... " " " " 3. Centre .....	13.6 13.8 10.6	29.0 29.0 27.0	29.6 29.9 27.9	30.7 31.0 28.7	35.5 35.5 34.5	13 13 13

Specification D.T.D. 364A, and used in the artificially aged condition. The 0.1% proof-stress values obtained on the German material, although of a high order, are lower than would be obtained from artificial ageing, and it is considered that the mechanical properties of the German extrusions have been obtained by straining and natural ageing.

The extruded Japanese spar flange contained approximately 2% copper, 8% zinc, 1% magnesium, and 0.5% manganese (Table I). Apart from a higher copper content, the composition is similar to that of the American alloy X76S. As shown in Table II, the Japanese material had an average tensile strength of 35 tons per sq. in., and an average elongation value of 13% on 1 in. gauge length.

## British Iron and Steel

(Continued from page 138)

largely based. Since those early days the British iron and steel industry has continued to progress, and there is no indication of sterility or decay in its make-up to-day. Indeed, the reorganisation of the industry as a whole has greatly enhanced its future prospects, as, with the formation of the British Iron and Steel Research Association, co-operative research within the industry will be able to accomplish much that would be extremely difficult or impossible by individual firms. That research will proceed on a bigger scale is practically assured, but there seems to be no likelihood of developments in the immediate future changing the basic methods of production. To obtain increased economy, attention must be given to plant and to details in production, and economy in production must be judged not so much with respect to the cost of similar products by other iron and steel producing countries, as by those factors which determine the cost of production in this country.

There is no doubt that at the outbreak of this war many firms had rebuilt their blast-furnaces and carried out improvements to steel furnaces and rolling mills and were well equipped to meet the great emergency. Other firms, on the other hand, had not commenced with their reconstruction schemes and were forced to leave them in abeyance in view of the emergency. Since all firms have been and still are working as near as possible to their maximum capacity, not only will the schemes for reorganisation involve considerable new plant, but it will be necessary to overtake the arrears of

repairs and maintenance, as quickly as possible after the conclusion of hostilities.

With a comparatively short time lag between the demands for war and those for peace, and it is likely that it will be almost imperceptible in the iron and steel industry, improvements will need to be carried out while still striving to produce at capacity. Thus the main difficulty is likely to be trying to meet the needs of all the industries requiring iron and steel, while at the same time modernising or replacing existing plant with a view to more economical production.

With progressive managements working in close co-operation with all the producing sections, to apply the results of scientific research and make use of the latest plant and appliances, the future is reasonably bright, but the main consumers could assist greatly by reducing the variety of their demands to enable the industry to produce supplies of particular products in greater bulk.

## Wrought Light Alloys Development Association

THE work of the above Association has greatly increased within recent months, and it has become necessary to take additional office accommodation adjacent to the present offices at Union Chambers, 63, Temple Row, Birmingham, 2. All communications should continue to be directed to this address, but owing to the increase of telephone calls, additional lines have been installed, resulting in a new telephone number. The new number is MIDland 0847, and all members of the Association staff can be obtained at this number through the private branch exchange installed.

## Reviews of Current Literature

### Metallography of Some Aluminium Alloys

THE work described in this report was originally undertaken in an attempt to correlate the casting characteristics of some of the aluminium alloys in general use with their constitution. This relationship is discussed in Research Report R.R.A. 629 of the British Non-Ferrous Metals Research Association, but it was thought that the metallographic information collected during the work might be of use, since the constitutions of the more complex aluminium alloys are not readily predictable from their chemical compositions, particularly under metastable conditions such as occur in most types of casting. No attempt was made to ensure that the alloys were in equilibrium and in fact the rates of cooling used approximate more nearly to those in castings than to those necessary to obtain equilibrium.

The work is divided into three sections: (1) Cooling curves were first taken on the alloys selected for investigation; (2) specimens were quenched from above and below each arrest point on the cooling curve; and (3) the structures of sand-castings of each alloy were examined. The alloys investigated included D.T.D. 424, NA 226, L5, L8, L11, L33, Y alloy, RR50, RR72B, Aeral A, and Alpac gamma.

The results obtained are summarised in several tables. No new information about the constituents likely to occur in the range of alloys investigated has been obtained, but the results are presented in a form which will be of great assistance to users of the commercial aluminium alloys in general use for castings.

By M. D. Smith, M.A., British Non-Ferrous Metals Research Association Report R.R.A. 635, November, 1943, 12 pp., 32 figs. Price 2s. Obtainable from the B.N.F.M.R.A., Euston Street, London, N.W. 1.

### The Works' Engineer

ALTHOUGH there are many books that deal with works' organisation, there are few that are concerned wholly with the maintenance organisation of a works, and the present book occupies a high position of usefulness amongst these few. The fact that the first edition is out of print, and that continued demands have necessitated a second edition, indicates in some measure that the method of dealing with the subject provides a general reference book on maintenance for the use of the works manager and the works engineer. It should not, however, be regarded as a technical reference book, but rather one in which helpful information is given to cover problems on maintenance, such as are likely to be encountered in works, and systems that have been tried and proved successful. In addition, the author offers suggestions as to where savings can be effected, and on the use of general service records.

It is still the practice in some works to make each department responsible for its own maintenance; apart from the overlapping and waste of time which takes place by such a policy, the maintenance costs considerably more than if maintenance is directed by a capable engineer, who, in addition, can frequently effect considerable economies in the use of essential services. In modern practice the works' engineer, through the works' manager, is responsible not only for the maintenance of

all the machinery and plant in the works, and for the personnel involved, but also for the introduction of new equipment to supplement or replace existing plant, and, in the absence of a planning engineer, for the planning of the layout of the shops and the choice of design of the actual machines. Obviously, the works' engineer must be possessed of initiative to a high degree, and be able to adapt the plant to meet the demands made by those in charge of actual production. This book will prove of great help to him in his work; it is essentially practical and sound.

The author deals with office organisation and routine in their application to the works' engineers' duties; the various plants making and using steam; water, gas, compressed air, and vacuum; electrical equipment; mill-writing and machine-tool repairs; fans and their application; the safety engineer's duties; fire brigade and fire equipment; factory heating; factory buildings; timber damage due to insects and dry rot; and various miscellaneous aspects, such as conveyers and transport, degreasing and cleaning of metals, lubrication, temperature measurement, etc. A list of more specialised literature is included in a bibliography which is mainly composed of manufacturers' technical publications.

By W. R. J. Griffiths, M.Inst.F., A.M.S.W.I.E., in collaboration with W. O. Skeat, B.Sc., G.I.Mech.E. A.M.I.Loco., E. 364 pp., 202 figs. Published by Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, London, W.C. 2. Price 21s. net.

### The Application of Radiant Heat to Metal Finishing

HEATING is used at one stage or another in a wide range of industrial processes for varying purposes, from the promotion of physical changes to the acceleration of chemical reactions. Until recently the most widely used methods of heat transfer were conduction and convection; in many cases, however, these methods were slow and not by any means the most suitable. The rapidly increased demands for war purposes has led to the need for greater economy in production time and for some reduction in the amount of floor space occupied by heating equipment. Thus, attention has been directed to other possible methods of transferring heat, with the result that radiant heating has been developed and it is this method of heat transfer which is discussed in this book.

Radiation has long been used as a means of heat transfer for industrial purposes. Many types of high-temperature furnaces rely very largely upon this method of heating, but it is only comparatively recently that it has been used to any great extent for relatively low-temperature processes, requiring temperatures up to about 300°C., and in this interesting book its use is concerned with the treatment or finish of metal surfaces, more particularly the drying of paint or other finishes applied to the metal.

There can be little doubt that war conditions have been responsible for the rapid introduction of electric radiant heat plant for paint or enamel drying, in view of the need for speed, the question of cost being a secondary consideration. By the use of special filament bulbs as the source of radiant heat, suitably arranged with respect to the surfaces to be dried, the time of drying could be reduced to about a fifth of the time taken in the usual type of gas-heated, convection oven. It was found that

the initial cost of the plant and the actual production costs were relatively high, and investigations resulted in the development of new gas-heated plants which are claimed to be more economical in these respects. The convection oven, however, according to the authors, is perhaps still the cheapest method of paint drying, although other factors, which cannot be classed as direct operating costs, often militate strongly in favour of radiant heat.

The advent of the radiant heating unit, however, has had a profound effect on the whole question of industrial oven design, and whatever the future tendency, there can be no doubt that the experience gained as a result of its introduction will be of great value to industry as a whole. The application of radiant heat to metal-finishing will certainly have its place in peace-time production, and the authors have performed a useful service in emphasising, in this book, the fundamental principles of radiation plant design, paint formulation, etc., as future development must inevitably depend on the due appreciation of these factors irrespective of any particular features of plant design.

By J. H. Nelson, Ph.D., A.Inst., P. and H. Silman, B.Sc., A.I.C. 88 pp., 42 figs. Published by Messrs. Chapman and Hall, Ltd., 11, Henrietta Street, London, W.C. 2. Price 8s. 6d. net.

### British Railways

THE work of the railways nowadays is taken so much for granted that few pause to appreciate the vital importance of the work they do in peace and in war. Those who can afford the time to read a booklet recently issued by British Railways Press Office will be more than compensated for their trouble: it gives a brief account of the work of the British railways and the story is told in such a way that the reader becomes enthralled. Indeed, so interesting is this story that the average reader will not be disposed to lay it down until he has completed it. For those who feel they can ill afford the time for reading, the illustrations in themselves tell a story, and these are so excellently reproduced that they give pleasure as well as some idea of the work that never ceases.

It is noteworthy that this year is an important year in British railway history, since it marks the coming of age of the amalgamation of the four main-line railway companies, and as an introduction brief reference is made to the origin of these four groups, which assists the reader to appreciate the tremendous amount of reorganisation of the railway system effected between the wars. That British railways were ready for the greatest test that could be made of any undertaking was due to the energy and foresight displayed in this reorganisation. With the outbreak of the second great war the main line railways were able to place at the country's disposal an asset of supreme national and strategic importance. Undoubtedly, the steady and progressive policy of improvement adopted and pursued until the war called a halt has enabled the railways to meet the rail transport requirements necessary to Great Britain and her Allies for the successful prosecution of the war.

But this booklet is not only concerned with progress between the great wars, it also gives a very convincing story of the railways at war, and tells of some of the difficulties surmounted, also the thrilling experiences of

some of the personnel. This booklet is an excellent production and a credit to British railways.

Issued by British Railways Press Office, Waterloo Station, London, S.E. 1, on behalf of G.W.R., L.N.S., L.N.E.R., S.R., and London Transport; price 1s. net.

## Post-War Building Materials

### The Claims of Aluminium

**A**LUMINIUM by itself and unalloyed with other metals has possibly little or no claim as a building material, at least in a structural sense; but as the main constituent of many important alloys, some of them only of recent introduction, it promises to achieve high rank among the so-called newer materials of building. In a recent lecture to members of the Incorporated Association of Architects and Surveyors, Dr. E. G. West (of the Wrought Light Alloys Development Association) gave some interesting details of the possible contributions of aluminium alloy to the all-important national problem of post-war building. Its uses here will doubtless be increased by further extensions of the prefabrication principle, already largely applied in building and by no means restricted to merely temporary dwellings. The properties of aluminium alloys, of which the most noteworthy are low weight—about one-third that of steel,—high resistance to corrosion, great strength, and pleasing appearance, have appealed to many authorities as particularly valuable in the manufacture of prefabricated units—e.g., for kitchen or bathroom. Even in pre-war days these alloys were very extensively used in high-class office blocks, hotels, civic and other public buildings, luxury flats, shops, hospitals, and ocean liner interiors; and more recently in some of the latest housing schemes, such as those of Coventry and Birmingham, they are used in many and varied ways. These include fabrication in large units, such as walls, roofs, or floors, and are an important factor in speedy and economic house erection. It must be remembered that there now exists a wide range of aluminium alloys suitable for different purposes, and W.L.A. Development Association has collected much valuable information as to these specific uses, and would be glad to give architects and others full advice thereon. At present all these alloys are covered by specifications for aircraft purposes, but British standards for aluminium alloys suitable for building and general engineering will be available shortly.

Although no indication has as yet been given by producers regarding the all-important question of costs, Dr. West stressed the fact that the production of aluminium and its alloys has now been increased on such a vast scale that there is every prospect of substantial reduction in costs. Even at present levels, however, these alloys occupy a strong competitive position.

### The Royal Aeronautical Society

At a recent meeting of the Council of the above Society the following officers were elected for the year 1944-45:—President: Sir A. H. Roy Fedden M.B.E., D.Sc., F.R.Ae.S. Vice-Presidents: Mr. W. C. Devereux, F.R.Ae.S.; Mr. R. K. Pierson, C.B.E., F.R.Ae.S. They will take up their respective offices on October 1, 1944.

# MICROCHEMISTRY

APPARATUS · METALLURGICAL APPLICATIONS · TECHNIQUE

JULY, 1944

METALLURGIA

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*IT has now been confirmed that the first meeting of the new Microchemical Group of the Society of Public Analysts will coincide with the October meeting of the Society. Presumably, the intention is to hold elections of office-bearers at this meeting, since no indication of an alternative method of election has been announced, and it seems obvious that office-bearers should be elected, either prior to, or during the first meeting. As will no doubt be apparent by now to our readers, we are not in favour of anything which might unjustifiably delay the germination of the Group. However, we feel strongly that an election which would give undue weight to one section of the members is something to be avoided at all costs. Any body elected in these times at such a meeting must inevitably tend to represent the views of the London members more than proportionally. This is not a mere provincial quibble, for in addition to being our own view, it has been expressed to us, more or less directly, by other chemists living both in and outside London. It may be, of course, that such a possibility has been envisaged by the Council of the Society of Public Analysts, and that they are taking, or have taken, steps to avoid it. It still seems to us, however, that as far as elections are concerned the fairest, as well as the simplest and speediest way is to rely, as so many of the National Societies rely, on the postal ballot.*

## Analysis by Internal Electrolysis—A Semi-Micro Method

By James G. Fife, M.Sc., Ph.D., F.R.I.C.

*Electrolytic methods, as adapted to dealing with small quantities of material, have been described in a previous article. One interesting development of such methods, which has been perfected comparatively recently, is based on the deposition of metal without the use of an external current. The method and some of its applications are dealt with in this article.*

THE term "Internal Electrolysis" was first employed by Sand,<sup>1</sup> and refers to electrolysis without the application of current from an outside source. The principles underlying internal electrolysis were employed industrially over one hundred years ago in electrotyping and similar processes by Elkington and Barratt,<sup>2</sup> Jacobi,<sup>3</sup> Jordan,<sup>4</sup> and Spencer.<sup>5</sup>

Internal electrolysis, as applied to chemical analysis, enables as little as 0.5 mgm. of a more noble metal—e.g., copper—to be quantitatively determined in the presence of 5 gms. of a less noble metal—e.g., iron or zinc.

### Basic Principles

The principles underlying the method may be briefly explained as follows:—

Let us consider a cell in which the anode and cathode compartments are separated by a parchment membrane and in which the anode consists of a metal of high

solution pressure (a less noble metal, such as zinc or iron) in contact with a solution of one of its salts, which constitutes the anolyte. The catholyte contains not only a salt of the metal of which the anode is made, the concentration of ions of the anode metal in the catholyte being slightly lower than in the anolyte, but also contains a salt of another metal of lower solution pressure (a more noble metal, such as copper). The cathode may consist of the metal of lower solution pressure, or of a metal of even lower solution pressure, or of a wholly indifferent metal, such as platinum. Then if the two electrodes are short-circuited a current will flow owing to the discharge of the more noble ions on the cathode, and the anode will dissolve with the production of ions of the baser metal. This will not be followed by a deposition of the anode metal on the cathode owing to the higher concentration of ions of the anode metal in the anolyte than in the catholyte.

It is upon the foregoing principles that the process of analysis by internal electrolysis is based, but there are some other factors which must also be considered.

<sup>1</sup> Sand. *Analyst*, 1930, **55**, 309.

<sup>2</sup> Elkington and Barratt. B.P. 7742 of 1838.

<sup>3</sup> Jacobi. *The Athenaeum*, 1839, 334.

<sup>4</sup> Jordan. *Mechanic's Magazine*, 1839, **31**, 163.

<sup>5</sup> Spencer. *Trans. Lit. and Phil. Soc. of Liverpool*, Sept. 12, 1839.

These are briefly as follows:—

- If a complete deposition of the metal to be determined is to be attained within a reasonable period of time there must be effective stirring of the catholyte, particularly in the immediate vicinity thereof.
- The conditions must be such that the deposit will adhere to the cathode.
- The conditions must be such that no undesired material—e.g., colloidal hydroxides—is deposited on the cathode.
- Complex ion formation of the metal to be determined must not take place to such an extent as to hinder its complete deposition.
- The formation of badly conducting films, particularly on the anode must be rendered impossible.

#### Apparatus of Sand

A number of early attempts to apply internal electrolysis as a method of chemical analysis were made, the first being by Ullgren,<sup>6</sup> but the method was first made

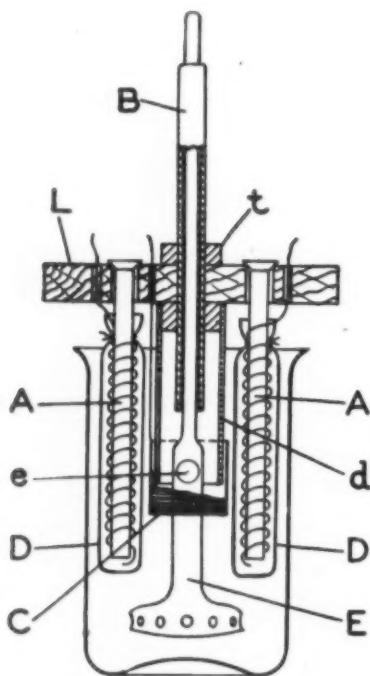


Fig. 1.—Modified apparatus for internal electrolysis.

rapid and of practical importance by the apparatus devised by Sand.<sup>1</sup>

The apparatus was afterwards slightly modified by Fife,<sup>7</sup> and this modified apparatus is shown in Fig. 1. The electrolysis vessel consists of a 300 ml. beaker. The special stirrer E has 12 small holes disposed around its periphery at the bottom. A larger hole *e* allows of the circulation of the liquid in the immediate vicinity of the platinum cathode C. The cathode is supported by the glass tube *d*, which fits around a cork annulus. This

annulus in turn fits around the tube B, which serves as a guide tube for the stirrer E. The anodes consist of wire or tape of the less noble metal wound around flanged glass tubes A, arranged as shown in the lid L, which is made in one piece. The parchment diffusion shells D are attached to the flanged tubes by rubber bands. The apparatus is used in association with the stand described by Sand,<sup>8</sup> and the cork annulus *t* is provided to be held in the clamp of the stand.

The original Sand apparatus or the modified apparatus described above have been used to determine small proportions of various more noble metals in the presence of large proportions of various less noble metals. The following are representative determinations:—Bismuth and copper in lead bullion,<sup>9</sup> cadmium and copper in zinc ores and spelter,<sup>10</sup> bismuth in lead ores,<sup>11</sup> the separation of lead and antimony and the determination of lead in tartar emetic,<sup>12</sup> cadmium zinc,<sup>7, 10</sup> nickel in zinc,<sup>7</sup> copper in steels,<sup>13</sup> silver in galena and cupreous iron pyrites,<sup>14</sup> mercury in copper and zinc,<sup>15</sup> copper in cadmium,<sup>16</sup> and cobalt in zinc.<sup>17</sup>

#### Other Types of Apparatus

Other modifications of the Sand apparatus have been proposed, including the apparatus of Clarke, Wooten and Luke.<sup>18</sup> These workers used alundum thimbles instead of the parchment diffusion shells, on the ground that the shells were liable to attack by the acid solutions used. The experience of the writer and others does not confirm this objection to the use of parchment shells, except possibly in the case of somewhat concentrated hydrochloric acid. In any case, the shells can easily be changed while the use of alundum thimbles has the disadvantage that they bring about a large increase of resistance. A modification of the apparatus of Clarke, Wooten and Luke has recently been described by Yeck and Zischkau.<sup>19</sup> This also uses alundum thimbles.

Lurie and Ginsburg<sup>20</sup> have described a very simple apparatus illustrated in Fig. 2. In this apparatus the anode 1 consists of a bent plate of refined lead. This is used in conjunction with a Fischer's platinum gauze cathode 2. In the horizontal arm of the anode a hole is made so near the bend that the plate, when put in the gauze, is just in the centre. To secure a full contact the electrodes are firmly bound together with a copper wire 3. Lurie and Ginsburg state that they have found that the diaphragm could be successfully dispensed with and that the results obtained without it were no less accurate than in apparatus provided with a

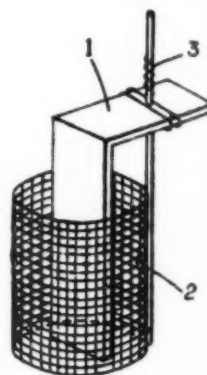


Fig. 2.—A simple apparatus described by Lurie and Ginsburg.

<sup>8</sup> Sand. *Analyst*, 1929, **54**, 275.

<sup>9</sup> Collin. *Analyst*, 1930, **55**, 312.

<sup>10</sup> Collin. *Analyst*, 1930, **55**, 495.

<sup>11</sup> Collin. *Analyst*, 1930, **55**, 680.

<sup>12</sup> Collin and Sand. *Analyst*, 1931, **56**, 90.

<sup>13</sup> Fife and Torrance. *Analyst*, 1937, **62**, 29.

<sup>14</sup> Fife. *Analyst*, 1937, **62**, 723.

<sup>15</sup> Fife. *Analyst*, 1938, **63**, 650.

<sup>16</sup> Fife. *Analyst*, 1940, **65**, 562.

<sup>17</sup> Fife. *Analyst*, 1941, **66**, 192.

<sup>18</sup> Clarke, Wooten and Luke. *Ind. Eng. Chem., Anal. Ed.*, 1936, **8**, 411.

<sup>19</sup> Yeck and Zischkau. *Ind. Eng. Chem., Anal. Ed.*, 1943, **15**, 221.

<sup>20</sup> Lurie and Ginsburg. *Ind. Eng. Chem., Anal. Ed.*, 1937, **9**, 424.

<sup>6</sup> Ullgren. *Z. anal. Chem.*, 1868, **7**, 442.

<sup>7</sup> Fife. *Analyst*, 1936, **61**, 681.

diaphragm. Lurie and his co-workers subsequently described various determinations carried out with the apparatus shown in Fig. 2 or similar apparatus. The writer has been unable, however, to confirm these results, and it seems that the Russian school have now returned to the use of a Sand apparatus with minor modifications.<sup>21</sup>

<sup>21</sup> Tschernichov and Schtutser, *Zavod. Lab.*, 1939, **8**, 801. (Abstracted *British Chem. Abs. C.*, 1944, Pt. 1, 3.)

The method of internal electrolysis is capable of giving accurate and rapid results, using the Sand or modified Sand apparatus, and is now used for various industrial analyses. The apparatus can be made up from material to be found in most laboratories, with the exception of the platinum cathode, which can be obtained from Messrs. Johnson Matthey and Co., Ltd., and the stirrer which can be obtained from most laboratory suppliers or made by a professional glass blower.

## Microchemistry and its Borderline : The Instrument as an Analytical Tool

By David L. Masters, M.Sc., Ph.D.

*Microchemistry is now becoming so highly developed that a complete grasp of all the instrumental methods, which it must be held to include, is beyond the grasp of the average practitioner. Specialisation, the obvious solution, will necessitate some readjustment of the system of using consultants, and a revision of the attitude towards the specialist consultant.*

**D**URING the last ten years or so there have been marked advances in the application of instruments to chemical analysis. It is true that early in this century, and even towards the end of last century, the spectroscope and microscope were being applied by progressive chemists to analytical problems. The latter instrument has not changed much in essential form or application since that time: the former has become "stream-lined" and in many cases highly automatic, but is nevertheless essentially the same instrument.

More recently colorimetry, from depending on a simple visual comparison, often rather unreliable, of two colours, has become increasingly precise, primarily as a result of the introduction of the spectrophotometer, the use of filtered light, and the photo-electric cell. Conductometric and potentiometric titrations require the installation of more and more complex "boxes of tricks" whose manipulation is a specialised though usually a simple operation.

The discovery of X-ray analysis (in the physical sense) was a revolutionary one from the point of view of the physicist. The utilisation of X-rays in problems which were previously regarded as purely chemical was equally novel in the experience of the chemist. Even more spectacular in both fields was the introduction of the electron beam as an investigating aid, leading on the one hand to many fundamental discoveries regarding molecular structure, and on the other to the now well-known electron microscope.

Polarography is daily being applied to an increasing number of analytical problems, both inorganic and organic, as is its off-shoot, the amperometric titration. A method has been developed recently for the determination of potassium by measuring its natural radioactivity. This is related to the determination of heavy radioactive elements, and parallel methods use artificial

radioactive atoms. Likewise, the mass spectrograph has been applied in non-radioactive tracer experiments, and has been further developed to analyse, rapidly and economically, quite complex mixtures of gases and vapours. It is now being marketed for this purpose in America.

Infra-red spectroscopy, formerly of prime use in the investigation of molecular structure, has now been developed to handle analytical problems; while it is proposed that the use of the closely related Raman spectrum should have a like extension.

One of the most recent developments is that based on the electron microscope. When electrons pass through a thin film of material they suffer discrete energy losses which are related to the electron shells of the atoms composing the film. From a record of these energy losses it is possible to determine which atoms are present in the film of material. An electron probe is used, first of all to pick out a desired field in an electron microscope, and subsequently by a simple conversion of the instrument to transmit through that field electrons whose energy losses may be determined. The results indicate the exact location of elements in an area containing as little as  $10^{-14}$  to  $10^{-16}$  g. of material. Elements such as carbon, aluminium and iron have been detected in this way, and while the method is only in an experimental stage, it seems probable that it can be usefully developed for certain difficult problems.

### The Problem of Physical Methods

The reader is no doubt by now beginning to realise that because of these otherwise valuable extensions a serious problem is becoming apparent. This is underlined by the news (which appeared after the first draft of this article had been written) that the Society of Public Analysts, in addition to its Microchemical Group, is considering the possibility of forming a group dealing

with physical methods of analysis, typical methods quoted being spectrographic, including mass-spectrographic, photometric, polarographic and X-ray diffraction.

The methods mentioned in this article are *most frequently employed to determine micro amounts*. But just because of this, it would seem that history is repeating itself. Microchemistry, together with the borderland already instanced, appears to be approaching a parting of the ways similar to that which affected chemistry as a whole fifty years ago. X-ray analysis has already split itself off from the main body, if, indeed, it ever was in it. The introduction of additional applications in spectroscopy is rendering it more complex, and many microchemists will frankly admit that they have never seen or handled a polarograph.

It is not easy to propose a solution or to suggest desirable lines of development. It seems clear that in future the general microchemist, and still more the general analyst, will not be able to range over the whole field. For one thing, no consulting chemist, for example, could hope to acquire all the necessary apparatus to enable him to apply all the methods, even if he could afford the time to make him expert in handling it. Industrial firms, likewise, are faced with the course of employing a large specialised staff, much of whose time will not be taken up directly with immediate problems; or with passing work out to consultants; or with, in the last resort, using a makeshift and unsuitable, but readily available analytical technique.

#### General and Specialist Analysts

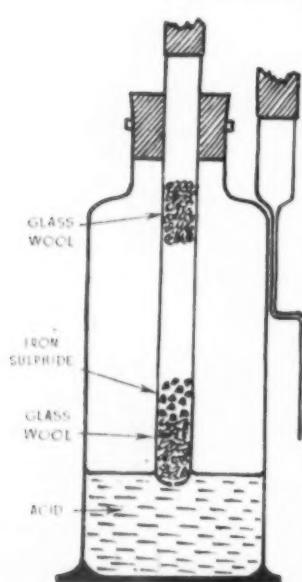
To the writer it seems that the problem is one to be solved by an increase in consultants (or consultant

bodies), but only if some radical developments arise in the attitude towards the consultant. It might be well, perhaps, if the science in this instance took a lead from the medical profession. There two distinct categories exist side by side, the general practitioner and the specialist. Ideally, at least, the patient approaches the G.P., who decides, on the merits of the case, either that he can handle it, or else that it is the job of such and such a specialist, to whom he hands over the patient. Conversely, an eye specialist would never think of treating one of his patients for boils or whooping cough.

A system capable of dealing competently with analytical problems must function something after the same manner. Naturally, this conclusion is a masterpiece of understatement. For one thing, it is not always clear which specialist is more suitable for an analytical problem, although as time goes on and research continues this will become better defined. But, more important, the labourer must be worthy of his hire. Unless the general public makes it worth a man's while to specialise, and more especially to handle *only* specialised problems, he will continue to spread his energies and so, in large part, to waste them.

And finally, the education of the general analyst must be broad enough to render him capable of distinguishing clearly between general and specialised problems, and of directing the latter to their proper home. Only in this way will it be realised that it is really an acknowledgement of his grasp of his subject when a consultant refers a problem to a specialist, whether it be in medicine, law or chemistry; and that it is a reflection on the organisation of the chemical profession if the average consultant must do his best with inadequate apparatus through no fault of his own.

#### An H<sub>2</sub>S Generator



WHILE numerous schemes of micro-qualitative inorganic analysis which do not require the use of sulphuretted hydrogen have been proposed, the most satisfactory and most widely used methods still employ the gas as a major reagent. Ordinary supplies of H<sub>2</sub>S are difficult to adapt to micro use, partly because it is not easy to produce sufficient gas pressure to drive the gas through the hair-tip capillaries which serve as delivery tubes.

The requirements for a micro-H<sub>2</sub>S generator are: (1) that it should be compact and sturdy; (2) that it should give a high-pressure delivery of gas; (3) that it should

nevertheless not produce large excesses of gas which may escape into the atmosphere on ceasing to use the generator; and (4) that it should preferably be of simple

construction. A generator recently described<sup>1</sup> conforms to several of these requirements, and may be further modified to make it even more satisfactory.

In its modified form it is illustrated in Fig. 1. The outer vessel may be a bottle or any other flat based tube which will be reasonably steady. (The original apparatus employs a test-tube, which therefore requires to be clamped.) The inner vessel is a length of glass tubing (5-8 mm. diameter) which has been almost, but not quite, sealed off at one end. In the inner tube there is first a layer of glass wool about 1-2 cms. deep, followed by a layer of small pieces of iron sulphide. It is advisable to add another layer of glass wool above this to prevent spray and bubbles of liquid from passing. The delivery tube may be left loose, or may be attached to the outer vessel by tape, in the position shown, being then suitably bent to allow centrifuge tubes to be raised under the tip.

To start the flow of H<sub>2</sub>S, the stopper bearing the inner tube is inserted into the outer vessel, which contains acid. To stop the flow the stopper is removed, and resistance in the capillary to the gas flow rapidly drives the acid back from the iron sulphide into the acid reservoir. Very tiny bubbles may be obtained by this apparatus, and as an added convenience several delivery tubes giving bubbles of different sizes may be attached permanently to the vessel. By switching the rubber connection, the most suitable jet for any purpose may be brought into service quickly.

<sup>1</sup> S. Gaddis, *J. Chem. Educ.*, 1944, **21**, 101.

## Nitrogen as a Constituent of Stainless Steels

By A. Samarin, A. Yaskevich and I. Paisov

THE Moscow Steel Institute carried out a series of experiments aiming at creation of a stainless steel containing less nickel and more nitrogen than the usual 18-8 steel; the advantage expected was not only a reduction in costs but also saving of nickel, which is not abundant in Russia.

The alloys were made by melting together Armeo iron with nickel, and ferro-chromium (free from carbon) or chromium. To this melt were added either (a) nitrided chromium or nitrided ferro-chromium, followed by ferro-manganese and ferro-silicon, then by ferro-titanium, and finally by 0.1% of aluminium, or (b) ferro-manganese and ferro-silicon, followed by nitrided ferro-titanium and 0.1% of aluminium. The nitrided ferro-chromium and ferro-titanium were prepared by heating ferro-chromium or ferro-titanium at 900-950° C. in a current of nitrogen and the nitrided chromium similarly at 1200-1300° C. They contained 1.4-2.8% of N (ferro-chromium), 2.6% of N (chromium), and 3.6% of N (ferro-titanium). Of the nitrogen thus introduced into the melt, about 0.5 (chromium and ferro-chromium) to 0.9 (ferro-titanium) remained in the cold casting.

The alloys prepared belonged to three types. Type I was very similar to the usual 18-8 steels; the composition of its alloys was confined within the limits C 0.06-0.14, Cr 18.1-22.5, Ni 8.6-9.8, N 0.02-0.05, Mn 0.2-1.2, Si 0.2-0.5, and Ti 0.0-0.8%. Type II was characterized by a low nickel and a low nitrogen content: C 0.04-0.17, Cr 17.8-21.6, Ni 4.1-5.2, N 0.007-0.08, Mn 0.6-0.8, Si 0.2-0.5, and Ti 0.4-1.0%. Type III had a relatively low nickel and a relatively high nitrogen

content: C 0.04-0.23, Cr 14.2-21.6, Ni 2.6-5.1, N 0.11-0.25, Mn 0.5-0.8, Si 0.2-0.4, and Ti 0.1-1.4%.

Some of the castings of the Type III were full of pores and bubbles; apparently this effect depended less on the total nitrogen content than on the ratio N:Cr; the castings were sound as long as this ratio was less than 0.012. The porous alloys of Type III and an alloy of Type II cracked on cold rolling and were discarded. The remaining alloys were investigated (a) directly after cold rolling, (b) after a following quenching from 1150° C, (c) after a 72 hours action of boiling copper sulphate and sulphuric acid, and (d) after a 24 hours annealing at 600° C. Table I gives the results of tensile and elongation tests for these alloys.

TABLE I

	Type I	Type II	Type III
Ultimate tensile strength (kg./sq. mm.) after			
cold rolling ..	95-122	90-165	121-156
quenching ..	72-119	63-65	86-129
boiling ..	99-177	92-114	53-192
annealing ..	84-105	78-131	86-147
Total elongation (%) after			
cold rolling ..	6-13	1-6	1-23
quenching ..	24-44	12-39	4-45
boiling ..	5-22	2-5	1-20
annealing ..	7-23	8-13	7-25

An alloy of Type I and two alloys of Type III have been boiled for 96 hours in 55% nitric acid. Their loss of weight in grams per sq. m. per hour was 0.29

The alloys of Type I contained both after quenching and after annealing a very large percentage (82-99%) of austenite. The percentage of austenite in Type II was much lower: 34-81% in quenched and 32-44% in annealed state. Type III included alloys having as much as 99.5% of austenite in quenched and as much as 85% in annealed state as well as alloys containing 30% of austenite in quenched for Type I and 0.32-0.60 for Type III. and 22% in annealed state. As far as

the limited material allows a conclusion it appears that the boundary between austenitic and non-austenitic steels, which depends on the ratio Cr:Ni, is shifted to lower nickel percentages if the alloy contains nitrogen; 0.2% of nitrogen often are equivalent in this respect to 3% of nickel.

The best alloy which could be used instead of the 18.8 steels, contained Cr 17-19, Ni 5, and N 0.2%.

## Electrolytic Zinc Plating of Sheet Iron

By P. M. Lu'yanov and V. B. Belcstotskaya

THE authors undertook a study of the possibility of zinc plating sheet iron in the process of the electrolytic production of zinc from acid electrolytes, using insoluble anodes.

In the laboratory, specimens were degreased by cathodic treatment for five minutes, followed by anodic treatment for 30 seconds, followed by etching in 15% hydrochloric acid.

The best results as regards the adhesion of the zinc and porosity were obtained by plating from an electrolyte with 100-120 g/l Zn, an acidity of 25-30 g/l H<sub>2</sub>SO<sub>4</sub>, a current density of 4-5 amps/dm<sup>2</sup>, and an electrolyte temperature of 30-35° C. Under these conditions coatings having a thickness of 30-35 μ and a low porosity were obtained. The potential across the bath was 3.5 V.

Improved deposition could be obtained by using a 1 μ thick intermediate flash coat of brass.

Bright deposits were obtained by adding 6 g/l of dextrin to the electrolyte (acidity 18-25 g/l H<sub>2</sub>SO<sub>4</sub>). Coatings were 18-20 μ thick and had excellent adhesion. Successful results were also obtained with a circulating electrolyte to stimulate actual production condition: a neutral zinc sulphate electrolyte being continuously added to the cell from which the acid electrolyte was being removed.

In experiments on the industrial scale some of the aluminium cathodes

From *Izvestia Akademii Nauk*, Division of Tech. Sci., 1943, No. 5-6, p. 71.

were replaced by sheet iron cathodes. The sheet iron had previously been annealed and pickled. A second pickling was found to be undesirable.

Most of the tests were made with a current density of 5-6 amps/dm<sup>2</sup>, and acidity of 20-30 g/l. and with the electrolyte at a temperature of 30-32° C. Plating was continued for

30 to 40 minutes, coatings 25-35  $\mu$  thick being obtained. Adhesion was satisfactory, the coatings standing up to 11-13 to-and-fro bends.

Salt spray tests showed that the electroplated specimens more than satisfied requirements as to corrosion resistance which have been laid down for galvanised sheet.

## Alumina from Clay—A Summary of Processes

**THREE** developmental alumina-from-clay plants are to be erected in the United States with U.S. Defense Plant Corporation funds. One, located in South Carolina, will operate on local kaolins; another, in Oregon, will use Pacific Coast clay; and a third, in Wyoming, will use feldspar. All of the alumina-from-clay processes are concerned with the basic problem of separating the alumina from other materials in the clay, principally iron and silica.

The South Carolina plant will use the lime-soda sinter process. This consists of first working crushed limestone and mashed kaolin clay in a tube mill, a little over 2½ tons of limestone being required per ton of clay. The mixture from the mill is filtered and the clay and limestone cake calcined in a rotary kiln, driving off carbon dioxide. The sinter is leached with a sodium carbonate solution which gives sodium aluminate contaminated with silica. This product is suitable for processing in a Bayer plant, such as those now in use for purifying bauxite, or it can be recrystallised under pressure to get rid of the remaining silica and then treated with the recovered carbon dioxide to precipitate aluminium trihydrate, which is filtered off and calcined to alumina in a rotary kiln.

The process used in the Wyoming plant is similar to the first, both coming under the heading of alkaline processes. Also similar is the red mud reclamation process for recovering alumina carried down with the silica when the Bayer process is used on bauxite.

There seem to be two primary handicaps that the alkaline processes will have to overcome if they are to compete with bauxite: First, the cost of limestone and coal; about 5 tons of limestone and 1½ tons of coal are required to produce each ton of alumina. Secondly, locations where both clay and limestone are available in the quantities needed are few.

*Chemical Industries, January, 1944.*

Advantages of the alkaline processes are that they offer a by-product credit in calcium silicate, a material useful in the manufacture of cement, and they require relatively simple and inexpensive equipment.

The Oregon plant will use the ammonium sulphate process. Clay and ammonium sulphate are roasted together to form alum and ammonia. The alum is leached out of the sinter with water, leaving the insoluble silica, and then purified by recrystallisation. This recrystallised alum is then combined with the recovered ammonia to give aluminium hydroxide, which in turn is kiln-dried to alumina. Disadvantages of the process are the cost of ammonia and the fact that it does not make an intermediate product which could be diverted over into existing Bayer plants if necessary.

In addition to these three processes, one other, that of Kalumite, Inc., is being tried out in a Government-sponsored plant in Utah, which will eventually make 100 tons per day of alumina from alunite, a high-alumina potash ore. Although known deposits of alunite are estimated at only about 12,000,000 tons, Kalumite believes it will be able to modify its process to work on clays and low-grade bauxite. In the Kalumite process, alunite ore, which contains basic alum and potash, is leached with cyclic sulphuric acid of about 10% strength, giving potassium alum, which is crystallised. These crystals, when placed in an autoclave at 150 lb. per sq. in. (10½ kg./cm.<sup>2</sup>) pressure and 94° C., decompose into basic alum and sulphuric acid again, but this time the basic alum has an alumina content of 33% as compared with 20% originally. The regenerated acid, containing some of the potassium sulphate and about 15% of the alum, is recycled, while the rest of the alum that has crystallised is calcined at 1,000° C. to give alumina and potassium sulphate. The remaining acid

(about half of the original) is driven off as SO<sub>2</sub> during the calcination. If the process is used on clays, an outside source of acid is required.

Closely akin to the Kalumite process is the Phelps Dodge method for recovery of aluminium and potash from the ore flotation tailings of a huge copper mine in Arizona. This process, however, uses acid of 80% strength to obtain potassium alum, which is then dehydrated and calcined to give alumina, potassium sulphate and sulphur dioxide, the latter going to an acid plant. Make-up acid is made from sulphur dioxide obtained in the copper smelting. Advantages are ready-mined raw material and available SO<sub>2</sub>.

Still another process is one in which roasted clay is leached with concentrated HCl, separating the alumina and iron from silica as aluminium and ferric chlorides.

## Flash Butt Welding for Tool Tips

**I**N order to conserve materials, it has been common practice to use composite tools, in which a plate of high-speed steel destined for the cutting edge is attached to a holder made of cheap structural steel. The attachment is usually carried out by brazing or fusion welding with the addition of filings and borax. The employment of flash-butt welding for this process presents many advantages, and the special tool-holder developed by the A.E.G. for this purpose, and which can be used in conjunction with a standard flash-butt welding machine, is illustrated. The tool clamp proper consists of an upper and lower jaw made of steel, whilst the plate clamp for the high-speed tool tip is made of copper, in order to equalise the electrical resistances. The strength of the flash weld is very great and the weld zone can be even subsequently forged if necessary. The heat zone is very limited, and there is no danger of the high-speed plate being burnt. It is even possible to use plates already hardened, so that the tool only requires grinding before being ready for use. The use of unhardened materials is, however, generally recommended, as this facilitates grinding and at the same time enables the weld to be subjected to a proper test. For subsequent hardening, the temperature most favourable for the high-speed plate can be chosen without any danger of the weld cracking.

*From A.E.G. Z.F.D.I., vol. 88, No. 7-8, Feb. 1944, p. 27 (adv. section). By courtesy of R.T.P. 3<sup>rd</sup> Ministry of Aircraft Production.*

# Ageing and the Yield-Point in Steels

By J. R. Low and M. Gensamer

AS advantages would be obtained in the drawability of automobile body-sheet from a deep-drawing steel with a very low yield-point but an almost normal tensile strength, provided a reduction in the yield strength could be accomplished without sacrifice of ductility and fine grain size, experiments were carried out on a number of low-carbon, basic open-hearth steels of deep-drawing quality on the elimination of ageing and the yield-point by wet hydrogen treatment. Changes in properties and composition produced, by annealing in wet hydrogen, factors influencing the effectiveness of the wet hydrogen treatment, and impurities that cause strain-ageing and the yield-point in low carbon steels were dealt with.

The major portion of the investigation was carried out on the five steels given in Table I. Changes in mechanical properties produced by annealing in wet hydrogen were determined by means of Rockwell hardness tests; tensile tests, including lower yield-point, yield-point elongation, tensile strength, uniform elongation, total elongation; and strain-ageing measurements showing the percentage increase in yield-point caused by ageing after straining. The values for steel T-3 after wet hydrogen annealing for various periods at 710° C. given in Table II are typical of the results obtained.

The experiments showed, in general, that when low-carbon steel of the grades normally used for deep-drawing were annealed in wet hydrogen the yield-point which has been considered typical of steels containing large amounts of ferrite was completely eliminated and the stress for the beginning of plastic deformation was greatly reduced. Both strain-ageing and quench-ageing were also completely eliminated. The carbon and nitrogen contents of rimmed steels so treated were markedly lowered, and carbon was less than 0.003%, and nitrogen less than 0.001% after treatment. With aluminium-killed steels, there was some evidence to indicate that the nitrogen content was unaffected by the treatment, but the carbon content decreased as in rimmed steels. Upon completion of the treatment, all traces of cementite had disappeared. The treatment also appeared to effect the etching characteristics of the steels, particularly when using nital, and as the treatment proceeded it became more difficult to develop ferrite grain boundaries.

Among the variables examined as regards their influence on the effectiveness of the wet hydrogen treatment in eliminating the yield-point and ageing were the moisture content, temperature, specimen thickness, composition of steel, rate of gas flow, heating in air following treatment, cold-rolling

followed by heating in air, and nitrogen in the wet hydrogen. The time required for treatment decreased markedly as the moisture content increased from zero to 5%, but a further slow decrease was observed as the partial pressure of water was raised up to the maximum permissible without oxidation. If oxide formed on the specimen surface the treatment was ineffective. In the range 670° to 850° C. the time required for treatment passed through a minimum at 730° C., giving an optimum temperature range from 730° to 740° C. The relation between sheet thickness and time for complete elimination of the yield-point and ageing for rimmed steels under 0.08% carbon was given by the equation  $t = 8.7a^{2.4} \times 10^4$ , where  $t$  = time in seconds and  $a$  = sheet thickness in inches. Rimmed and killed steels in the same carbon range appeared to be very similar with regard to the effect of hydrogen treatment. Increasing the carbon content increased the time required, but did not affect the properties of the treated steel. Minimum time of treatment was obtained with a rate of gas flow above 0.01 ft. per sec.

Annealing in air at approximately 700° C. did not cause a return of the yield-point or ageing, but heating for short periods of time either at 885° or 940° C. in air, followed by cooling in air, caused slight return of ageing, but no return of the yield-point. Severe cold-rolling followed by "pack" annealing in air did not bring about any reappearance of strain-ageing, but a small yield-point was observed after this treatment. The presence of molecular nitrogen up to 10% by volume did not increase the time required to eliminate ageing and only slightly increased the time to eliminate the yield-point.

The presence of either carbon or nitrogen in amounts not greater than 0.003% is sufficient to produce both yield-point and ageing, and it was considered that considerably smaller amounts of either element were capable of producing such effects. This belief was based in part on the extremely short times required in special carbonising and nitriding experiments and in part on analyses of wet hydrogen-treated specimens in which the yield-point and ageing had just been eliminated. The role of oxygen was not completely clarified, since all of the materials used for carburising and nitriding contained oxygen as the result of the wet hydrogen treatment.

TABLE I.—COMPOSITION OF STEELS USED.

No.	Type.	Sheet Thickness, In.	Composition.				
			C.	Mn.	P.	S.	Si.
T	Rimmed	0.036	0.05	0.30	0.010	0.024	0.003
T-1	Killed	0.036	0.05	0.30	0.007	0.022	0.005
T-2	Killed	0.036	0.05	0.33	0.007	0.020	0.007
T-3	Rimmed	0.0365	0.08	0.38	0.008	0.020	0.007
T-4	Rimmed	0.0335	0.08	0.39	0.010	0.014	0.006

TABLE II.—EFFECT OF TIME OF ANNEALING IN WET HYDROGEN AT 710° C.  
Steel T-3 (Rimmed) Partial H<sub>2</sub>O, 216-218 mm. H.G. (29.5 Vol. %): 10% Strain; Aged 3 hours at 200° C.

Annealing Time, Hours.	Hardness Rockwell B.	Lower Yield Point, Tons/Sq. In.	Yield Point Elongation, % on 2 in.	Tensile Strength, Tons/Sq. In.	Uniform Elongation, % on 2 in.	Total Elongation, % on 2 in.	Strain Ageing, %.
1	56	17.0	7.5	23.4	—	—	29.6
1.2	56	16.7	9.0	22.5	14	24.0	32.5
1.4	49	15.6	8.6	19.9	19	31.0	20.6
1.6	46	15.4	8.5	19.0	26	37.0	17.5
1.8	45	15.2	8.0	18.5	29	42.5	8.7
2.0	43	15.2	7.0	18.3	32	44.0	1.5
2.2	42	14.7	6.5	18.5	33	47.0	—
2.4	43	14.7	6.0	18.5	32	45.0	—
2.6	39	9.8	1.5	18.3	32	45.0	—
2.8	35	7.6	0.5	18.3	32	47.5	—
3.0	32	6.5	—	18.3	31	48.0	—
3.2	32	6.9	0.3	18.3	29	46.0	—
3.4	32	6.5	—	17.4	32	46.5	—
3.6	32	6.7	—	18.3	29	44.5	—

From *Metals Technology*, 1943, vol. 10, No. 8; and *A.I.M.M.E. Technical Publication No. 1644*, 36 pp.

From the results of oxidation experiments, however, it was concluded that oxygen *per se* did not cause strain-

ageing, although it might have a secondary effect on the amounts of carbon or nitrogen required.

metal industry in the U.S.A. and in Great Britain was purely a war-time measure, and it will be difficult to find a peace-time market for the enormous plants now in operation.

## Set-Backs in the Wartime Expansion of the Light Metal Industry

**ALUMINIUM.**—The expansion of the American aluminium industry was originally mainly financed by the two leading firms concerned—the Aluminium Company of America and Reynolds Metal Co., and by the end of 1941 a total output of about 600 million pounds was achieved. This was stepped up by the Government financed expansion programmes of 1941 and 1942, which set up about a dozen additional plants, and also arranged for manufacturing facilities in Canada. Finally, in 1943, a combined Aluminium Board, in which the U.S.A., Canada and Great Britain are represented was set up for the production and allocation of aluminium among the United Nations. As a result of these activities, the total aluminium supplies reached over 3,000 million pounds in 1943. The phenomenal growth over the last few years is shown in the following table (figures in million pound units).

	1937.	1940.	1941.	1942.	1943.
U.S. production .....	327	415	615	1,042	1,840
Canadian production .....	170	218	415	672	1,006
U.S. scrap .....	50	?	?	370	328
Total Supplies .....	547	(633)	(1,030)	2,084	3,374
Structural weight of U.S. built aircraft .....	?	?	87	291	742
Ratio, as a % of U.S. Al production .....	?	?	14%	28%	40%

Towards the end of 1943 a reserve of over 100 million lb. of aluminium not urgently needed, had accumulated and large quantities of Canadian aluminium, originally earmarked for the U.S.A., could be placed at the disposal of Great Britain and the U.S.S.R. The supply is now in excess of demand and a large number of the 60 plants operating in the U.S.A. at the beginning of 1944 are being closed down, thus cutting production to approximately one-half.

**Magnesium.**—In 1938 the total magnesium production in the U.S.A. amounted to less than 5 million pounds, and was thus quite insufficient to cover any war-time requirements. The American war production authorities have so far spent about 500 million dollars (mainly in the form of financial assistance to the leading producer,

Dow Chemical Co.) so as to build up plants with an annual capacity of 700 million pounds by 1943 (150 times pre-war capacity). Actual production, however, lagged considerably behind estimate with the result that the estimated requirements of about 450 million pounds for that year were not met. This is shown in the following table:—

1939.....	6 million lb.
1940.....	12½ "
1941.....	35 "
1942.....	100 "
1943.....	391 "

As a result, the managements of several of the plants were severely criticised by the Truman Committee. Meanwhile, the lack of magnesium has been made good by drawing on aluminium supplied and replacing magnesium incendiaries to a large extent by phosphorous bombs. The position, in spite of the waste disclosed, is thus not considered dangerous, especially as Canada after covering its own needs in 1943 is now reported to be ready for

export. The magnesium production in Great Britain during the war period is not known. In 1939 about 11 million pounds were produced. From the report of the House of Commons Select Committee on National Expenditure, it appears that till recently there were four firms producing magnesium in Great Britain, each of which used a different process, at a cost ranging from 1s. 6d. to over 4s. a pound. (The average price of magnesium in the U.S.A. was of the order of 20½ cents or 1s. a pound in 1943.)

Two of the processes had never been tried before on a large scale, and are now to be closed down entirely. Production at the other two plants is being curtailed, imports from America meeting the difference. This is rendered easier by the reduction in the magnesium content of modern incendiary bombs.

Very rapid expansion of the light

## Heat-Treating Bronze Castings

By J. W. Horner and F. A. Mason

**H** EAT-TREATMENT to cure porosity in some classes of bronze castings is applicable only to certain conditions of metal structure and the treatment described can be used only on castings that are structurally sound and are made by satisfactory foundry methods. Castings which leak under pressure due to lack of feeding or proper gating, poor design and pattern construction, gas or steam porosity, dirty metal or dirt from mould or core washings, impurities in the metal and dendritic unsoundness cannot be treated satisfactorily. Heat-treatment relieves stresses or strains produced by different working or cooling conditions and produces grain refinement and by so doing tends to produce porosity in pressure castings.

To determine the most suitable treatment for unsound bronze castings, two valve bodies of 35 pounds weight each, both of which leaked at the diaphragm and one of which had a stud and body leak, were heat-treated for 2 hours at 760° C. After heat-treatment, the castings were sand-blasted, reassembled and tested. One casting was satisfactory but the other casting leaked at a flange on the body. This leak was due to a tear resulting from poor foundry practice. Twenty-five valve bodies of the same size which had been rejected because of body, diaphragm and stud leakage, were next heat-treated at 650° C. for two hours. Out of the twenty-five valves treated, twenty-one passed a satisfactory pressure test, after treatment, and two of the remaining valves were satisfactory after a further heat-treatment at 650° C. for two hours. A number of high pressure valve bodies tested at 450 lbs. per sq. in., and rejected because of porosity were also heat-treated at 650° C. for 2 hours, and after treatment were found to be satisfactory. Out of 150 valves rejected because of leakage, over 90% were saved by heat-treatment at 650° C.

As a result of the above tests, all production castings were heat-treated before the sandblasting operation and

*Inter Acia*, No. 913/14, April 4, 1944, pp. 1-9. By courtesy of R.T.P. 3, Ministry of Aircraft Production.

as the result of such treatment, the percentage of rejections due to porosity dropped in some cases from 50% to a normal 3 to 4%. Heat-treated castings not only did not leak, but were also stronger, closer grained and had no interfering forces in the structure. To determine if ordinary physical properties were affected by the heat-treatment, an experiment was made on test bars cast from a heat of value bronze under wedge type rising feeders and fed with the maximum metal, so that the as-cast bars were not subject to differential cooling and therefore

were not stressed or strained. To test, bars were machined from the rough test-bar castings and two others were heat-treated and then machined. On testing, the as-cast test bars had an average tensile strength of 17.3 tons per sq. in. and the heat-treated test bars an average tensile strength of 17.0 tons per sq. in., showing that heat-treatment had little effect on the strength properties. A slightly more uniform structure was obtained in the heat-treated test bars.

From *The Foundry*, 1944, vol. 72, No. 3, pp. 109, 187-189.

## A New Method of producing Fechrall Steel

By Ya. L. Rosenblit

**P**RIOR to 1940 the electrical resistance alloy Fechrall (12-15% Cr, 3.5-5.5% Al) was produced at the Serp i Molot Works by melting in an 8-ton arc furnace. Carbon steel scrap was melted down, ore was added to reduce the carbon content, and after removing the slag the metal was deoxidized by treating with a deoxidizing slag, after which low-carbon ferrochrome was added. The alloy was tapped into a ladle containing the required quantity of molten aluminium and was then cast into ingots.

The alloy produced in this way was unsatisfactory, because of its gas content, and the cracking during rolling, due to the relatively high carbon content, and the presence of other impurities.

A new method of separate melting was developed to overcome these difficulties. It can be used successfully not only for Fechrall but also for the production of other high-alloy steels. In the case of Fechrall the procedure is as follows:

Low carbon steel is produced in an open-hearth, with a carbon content of 0.025-0.05%. If required the carbon can be reduced to 0.020-0.025%. The charge consisted of 15.5 tons scrap iron and 6.0-6.5 tons pig iron (0.015-0.042% S and 1.5% Si). In 18 heats the composition of the open-hearth slag varied between:  $\text{SiO}_2$  8.0-16.8%,  $\text{P}_2\text{O}_5$  0.10-0.36%,  $\text{Al}_2\text{O}_3$  0.54-12.8%,  $\text{Fe}_2\text{O}_3$  1.38-6.60%,  $\text{FeO}$  12.25-35.0%,  $\text{MnO}$  3.6-9.2%,  $\text{CaO}$  25.75-43.0%,  $\text{MgO}$  5.36-16.5%,  $\text{Cr}_2\text{O}_3$  0.50-1.95%, S 0.16-0.36%.

In the meantime the required amount of ferro-chromium is melted

and refined in an arc furnace. A long arc is used to reduce carbon pick-up. The charge used consisted of 6600 kg ferrochrome with 52-58% Cr and 0.09-0.15% C. The carbon content immediately before tapping had increased to 0.25-0.62 owing to pick-up from the carbon electrodes. By using graphite electrodes, or by melting in an induction furnace, molten ferrochrome with 0.04-0.06% could be obtained. Slags used for the refining of the ferrochrome varied in composition between:  $\text{SiO}_2$  21.2-32.8%,  $\text{P}_2\text{O}_5$  0.02-0.35%,  $\text{Al}_2\text{O}_3$  0.93-5.21%,  $\text{Fe}_2\text{O}_3$  0.2-0.6%,  $\text{FeO}$  0.72-1.97%,  $\text{MnO}$  0.28-0.94%,  $\text{CaO}$  42.2-64.5%,  $\text{MgO}$  6.3-18.4%,  $\text{Cr}_2\text{O}_3$  0.20-1.05%, S 0.09-0.26%. The slag was treated with ferro-silicon.

At the same time 1250-1300 kg of aluminium were melted in a ladle by means of an oil burner.

The molten and refined ferro-chromium is tapped into a tapping ladle, and from it into the ladle containing the molten aluminium. Into the same ladle is then tapped the open-hearth furnace charge. Care must be taken that only a relatively small quantity of the slag from the arc furnace and from the open-hearth furnace is allowed to enter the ladle.

The alloy is allowed to stand in the ladle, during which time the composition of the slag, as the result of reactions with the alloy, especially the aluminium, acquires the composition:  $\text{SiO}_2$  4.25-5.00%,  $\text{P}_2\text{O}_5$  0.05-0.10%,  $\text{Al}_2\text{O}_3$  45.19-54.02%,  $\text{MnO}$  0.20-0.4%,  $\text{CaO}$  34.0-36.8%,  $\text{MgO}$  3.5-14.8%,  $\text{Cr}_2\text{O}_3$  traces, S 0.09-0.21%.

Melts were cast into bottom-poured moulds. Ingots were allowed to cool in the mould; more recently cooling in annealing furnaces has been used.

The 18 heats of Fechrall produced by the separate melting process had compositions varying between: C 0.09-0.16%, Mn 0.32-0.69%, Si 0.25-1.00%, S 0.008-0.020%, P 0.016-0.028%, Cr 11.50-14.8%, and Al 3.87-5.05%. The carbon content of these alloys was less than that of alloys produced in the arc furnace.

Data which are quoted show that mixing in the ladle was adequate to produce a uniform composition.

The mechanical and physical properties of the Fechrall produced by the separate melting process were good. (Tensile strength 61.09-57.8 kg/mm<sup>2</sup>, elongation 31.0-26.0%, specific electrical resistance 1.50-1.14 ohms. mm<sup>2</sup>/m). Its heat resistance was superior to that of the alloy melted in the arc furnace. The important characteristic of the Fechrall produced by the new method was its satisfactory behaviour in rolling. This is probably due to its lower carbon content and the presence of fewer impurities, e.g.,  $\text{Al}_2\text{O}_3$  0.036% instead of 0.11% in arc-furnace-melted alloy. The separate melting process also has the advantages of a shorter time required to produce the alloy, a more effective use of plant and an appreciable fuel saving through the use of the open-hearth furnace.

From *Stal*, 1941, No. 5, pp. 17-22.

## Dynamical Brittleness of Metals

**I**T is often observed that the maximum deformation which a specimen can withstand without breaking is larger when the deformation is produced slowly than when it is rapid. The relation between the maximum compression  $\epsilon$  (i.e., the relative shortening of the specimen at which it cracks) and the rate of deformation is investigated more thoroughly using cylinders 1 cm. high and 1 cm. in diameter, compressed in the direction of the cylinder axis. For the majority of the experiments a "malleable cast iron" is used, containing C 3.1, Mn 27.79, Si 1.41, P 0.016 and S 0.15%. Its Rockwell hardness is 79-93, and its ultimate tensile strength (determined for cylinders 5 cm. long and 1 cm. in diameter) is 2190-2850 kg./sq. cm.

S. S. Erokhin, E. F. Nikolaeva and P. M. Ogibalov: *Inzhenernyi Sbornik*, 1943, 2, 3.

When the specimens are compressed to crushing within an hour or so, the crushing pressure is 2330 — 2600 kg./sq. cm., and the maximum compression is 23.2 — 25.6% (for 5 specimens).

For a rapid compression a pneumatic hammer is used. As its velocity cannot be varied independently of the pressure on it, at higher pressures several specimens are hit at once so that the force operating on one specimen does not change much. The experiment consists therefore in determining the pressure (and, consequently, the speed) at which 1, 2, 3, etc., specimens are crushed simultaneously. Table I gives the main results of the experiments.  $n$  is the number of specimens crushed at once,  $V$  is the speed of the hammer in cm./sec.,  $\epsilon$  is the maximum shortening of the specimen in %, and  $\frac{E}{2\pi n}$ ,  $M$  being the

mass of the hammer, and  $\pi$  the volume of the specimen ( $= \pi \times 12 \times 1$  cu. cm.),  $E$  is measured in kg./sq. cm.

TABLE I.

$n$	$V$ cm./sec.	$\epsilon$ %	$E$ kg./sq. cm.
1	980	21.7—22.2	1220
2	1700	23.5—24.5	1820
3	2250—2300	25.7—26.9	2148
4	2720—2740	26.0—26.5	2390
5	3160—3200	26.6—27.3	2580
6	3680	28.6—29.2	2880
7	4160	30.1—30.3	3160

It is seen that the value of maximum deformation at the speed of 980 cm./sec. is lower than that at very low speeds but, when the speed is raised further,  $\epsilon$  increases with  $V$ . This behaviour can be expressed briefly in the statement that the ductility of the alloy used has a minimum at moderate speeds of deformation. The rule according to which the maximum deformation is the greater the lower the rate of deformation, is not general.

A "special steel" gives similar results for the values of  $V$  equal to 0, 850 cm./sec., and 6000 cm./sec.,  $\epsilon$  values of 50%, 16%, and 34% are observed.

## "Blackening" Scale for Spectrographic Microphotometry

**PROKOFIEV**, of the U.S.S.R. State Optical Institute has recently<sup>1</sup> pointed out that the usual method of constructing a calibration curve from the data given by the non-recording microphotometer used in quantitative spectrochemical analysis involves a considerable number of unnecessary calculations. He recommends, instead, the use of a scale which gives a direct reading of "blackening" from the galvanometer deflection. The scale, which is simply constructed, permits the use of ordinary graph paper, without the need for taking logarithms and dividing pairs of galvanometer readings and, since it is a "blackening" scale, information is immediately given as to the portion of the characteristic curve of the plate which is concerned in any particular instance.

The principles of constructing calibration curves are derived from the following:—

(1) The analytical relationship between the intensity  $I$  of the spectral line and the concentration  $c$  of the given element, when expressed in logarithmic form, is linear over a certain range of concentration.<sup>2</sup>

$\log I = b \log c + a$  . . . (1)  
where  $a$  and  $b$  are constants.

(2) The law defining the relationship between the blackening of the photographic plate  $S$  and the intensity  $I$  of the light falling on the plate, is expressed by the formula:—

$S = \gamma \log I^p - j$  . . . (2)  
where  $t$  = time of exposure,  
 $p$  = Schwarzschild's constant,  
 $\gamma$  = factor of contrast,  
 $j$  = a constant for the plate.

(3) In quantitative spectrochemical analysis a comparison is made between the blackenings  $S_1$  and  $S_2$  of the two lines  $I_1$  and  $I_2$ . If these spectral lines are sufficiently close to one another for the corresponding values of  $\gamma$  and  $j$  to be indistinguishable, the difference in blackening is given by

$$S_1 - S_2 = \gamma \log I_1 / I_2.$$

From formula (1) and assuming that  $I_1$  refers to the element being determined and  $I_2$  to the internal standard we have

$S_1 - S_2 = \gamma b \log c + a_1$  . . . (3)  
where  $a_1$  is a new constant.

It follows from this analytical relationship that if the blackenings  $S_1$  and  $S_2$  occur on the straight-line portion of the characteristic curve then it is to be expected that a linear relationship should hold between the difference in blackening and the logarithm of the concentration.

The measurement of the blackening by means of the photo-electric microphotometer depends upon the following considerations. Let the quantity of light falling on the plate during the determination be  $i_0$  and that passing through the portion of blackening  $S$  be  $i$ , then the blackening is defined by the formula

$$S = \log i_0 / i.$$

Now, since it is known that the galvanometer deflection which measures the current passing through the photocell is proportional, within sufficiently wide limits, to the quantity of light falling on the cell we may substitute for the values,  $i_0$  and  $i$ , the corresponding proportional values of the galvanometer deflections,  $g_0$  and  $g$ . Hence:—

$$S = \log g_0 / g \quad \dots \dots (4)$$

The deflection  $g_0$  is taken to be that obtained by transmitting light to the micro photometer through the transparent part of the plate.

The difference in blackening of two spectral lines is given by the formula

$$S_1 - S_2 = \log g_2 / g_1$$

and combining this with formula (3) we obtain

$$\log g_2 / g_1 = \gamma b \log c + a_1 \quad \dots \dots (5)$$

in calculating the figures to be used for plotting a calibration curve from this formula it is usual to divide  $g_2$  by  $g_1$  and then either to plot the ratio against the concentration on double log paper if such paper is available or to plot the log. ratio against the log. concentration on ordinary graph paper. The operations of division and taking logarithms are possible sources of error.

The alternative method recommended is based upon a change of the microphotometer scale itself so that the blackening may be read off directly. It depends upon keeping  $g_0$  constant, so that formula (4) gives  $S$  as a function of the deflection for a given spectral line. The deflection  $g_0$  may change from plate to plate on account of variations in the transparencies of the glass and the emulsion layer, but it is always easy to arrange that it has a defined value by altering, for instance, the glow of the microphotometer lamp. In some cases the width of the microphotometer slit may be changed if this can be done without making it wider than or even equal to the width of the spectral line. A convenient value for  $g_0$  is 500 mm.

Since, therefore, it is always possible to achieve a constant deflection  $g_0$  for the transparent part of the plate, a log. scale of blackening may be drawn in place of the linear scale. This is done by setting down a numerical

1. V. K. Prokofiev: *Zavod. Lab.*, 1941, **10**, 76-77.  
2. S. L. Mendeleev: *Zavod. Lab.*, 1939, **8**, 786.

series of selected values for  $S$  and calculating for each value the deflection  $g$  from formula (4) transposed.

$$\log. g = \log. g_s - S,$$

or, if  $g_s = 500$ ,  $\log. g = 2.700 - S$ .  
The interval of blackening from 0 to 1.0 comprises the main part of the scale, about 450 mm. For  $g_s = 500$

it is possible to plot the scale by 0.01 to  $S = 1.4$  and thus to read to an accuracy of 0.01 or better.

The scale replaces the linear scale supplied with the instrument. Deflections are read directly as blackenings and calculations are made by simple subtraction, using formula (3).

## Automatic Control Features Zinc-Fuming Plant

By B. H. Hodgins

**C**OMpletely co-ordinated automatic control was no doubt responsible to some extent for the outstanding success of the new zinc-fuming plant at the smelter of the Bunker Hill and Sullivan Mining and Concentrating Company, at Kellogg, Idaho. The first test run lasted 28 days without a hitch in operation, after which the plant was shut down briefly for inspection. Designed to permit recovery of zinc both at current operations and from waste dumps, the plant is served electrically from a central substation, situated near the centre of the load. This building contains the 2,200- and 440-v. switchgear, the three-phase air-cooled power transformer, the metering equipment, and all 2,200-v. and 440-v. motor starters and air circuit breakers.

The centralised location of the substation made possible the co-ordination of all electrical starting functions and interlocking at a readily accessible point for most satisfactory maintenance. It also permitted the assembling of all the 114 440-v. motor starters, with their individual air circuit-breakers, in two compact, metal-clad units. In this manner, a large amount of installation time was saved, evidenced by the fact that there are 73 interlocked motor circuits in seven series and parallel conveyor groups.

The automatic "brain" of the plant is in a dust-tight central control room, near the fuming furnace. The usual boiler-room indicating and recording instruments, as well as the automatic control instruments, for pressure and flow of steam, and the various air supplies, are mounted in and on a control board. Co-ordinated with these controls and in the same room are three control cabinets containing electric relay and control circuits.

Protection and automatic control of the air pressure and flow are provided for the various coal pulverizers. Coal

is fed directly to the tuyeres under variable pressures, depending upon the depth of slag bath in the fuming furnace. For greater efficiency and reliability, such items as the hood draft damper of the deleading kiln, the uptake damper, the secondary air dampers to the fuming furnace, coal feed to the pulverizers, and speed of the bag-house draft turbine, are all controlled automatically, based on furnace conditions. Result of these automatically co-ordinated controls has been a minimum of time and material lost due to misoperation, and maximum efficiency has been obtained in the reduction of the zinc, effecting the maximum zinc elimination from the slag.

Automatic electrical control of the coal feed bins is part of the function

of the relay-control cabinets, which are in the central control room. With this equipment, a supply of coal under air pressure equivalent to that of the furnace tuyeres is constantly available to the pulverizers. Each of the coal bins is equipped with an air-pressure lock compartment and a main storage compartment. Pressure and mechanical limit switches which control electro-pneumatic coal flow gate valves and air pressure valves operate in sequence to fill the bins in a repeating cycle. The supply of coal from the bins to the pulverizers is maintained automatically by feeder controllers, which operate on a differential principle of air-pressure drop in the pulverizer to control electrically a two-speed feeder motor in the "off," "low," or "high" speed conditions. The electrical components of this control are incorporated in the general automatic control system.

Throughout, in these automatic operations, all important control circuits have been so arranged and grouped that master selector switches can be turned to block operation, or transfer from manual to automatic operation. The electric circuit arrangement is such that by the installation of automatic time-cycle controllers, now in hand, the entire fuming furnace cycle and the boiler starting and stopping cycle can be made fully automatic.

## Graphite Rods in Cast Steel Production

By F. J. Vosburgh and H. L. Larson

**F**ROM experiments with carbon rods as a means of reducing metal loss in risers of steel castings, it was found that results obtained were influenced by at least five controllable factors, namely, type of material in rod, shape of rod, size of rod, permeability of rod and position of rod. A series of experiments were therefore carried out on a standard size of casting with the same size of riser and pouring gate in each casting and several grades of carbon and natural graphite rods, including both porous carbon and porous graphite rods were experimented with. Square rods as well as round rods were tested. The various tests were carried out using a standard mould consisting of a single pouring gate, a runner joining two simple castings, and a single vented riser between the two castings and

above the runner; and a standard method of mounting the rods in the riser was also adopted. A 0.3% carbon steel was used and was poured at approximately 1590° C.

In the original experimental work core sand rods and rods made of welding carbons were used and it was found that the shrink cavities from both usages were similar. The shrink developed when using graphite rods, however, was radically different. With core sand and carbon rods elongated cavities were obtained while with graphite rods the cavities were flat-bottomed with the bottom just below the lower side of the graphite rod. As a flat-bottomed cavity lies high in the riser there is less chance of it entering the runner and progressing into the casting, and therefore the height of the riser should be reduced using graphite rods, thus saving in the amount of steel to be remelted.

The results obtained also showed that the shape of the rod, round or square, was of no importance, except, as round rods were less expensive than square rods, size for size, their use was preferable. The size of the rod in relation to the volume of the riser was an important factor. With too large a rod the carbon pickup was excessive, and might change the carbon content of the casting, while too small a rod resulted in cavities tending in shape towards those obtained when carbon or core sand rods were used. The degree of permeability of the rods was an unimportant factor and since rods having higher than normal porosity were more expansive, the standard rod was preferable.

The position of the rod in the riser was found to be important. If the rod was too high up, then the metal shrinkage carried the metal below the rod so far that the rod was not entirely used up by either combustion or absorption and some of the carbon was wasted. If the rod was too great a distance from the riser top, the desirable decrease in head height was not

obtained. This was because the shrink forms immediately above the rod and not with regard to the top of the riser. With too low a load it is probable that the top of the riser cavity would solidify and lessen the application of atmospheric pressure to the surface of the metal, though this was offset by the fact that holes were left in the riser sidewall where the graphite rod had burned out. For best results the rod had to be placed one-half the riser diameter from the top of the riser and 2 to 3 ins. from the centre line of the casting runner.

Absorbed carbon was found to lower the melting point of the riser metal, increasing its fluidity so that it flowed more freely, and combustion of some of the graphite rod increased the temperature of the metal adding to its fluidity. Because the riser metal was of higher temperature and more fluid than that of the casting and since atmospheric pressure entered through the riser flow-off or through the holes on the opposite side of the riser as the rods burned out, a head of liquid metal under atmospheric pressure was avail-

able for a larger casting feeding time than by other known methods. Also, because the metal is hotter and more fluid, the cross sectional area of the runners may be reduced, thus reducing cutting and grinding costs.

### Thermal Expansion of High-Silicon Cast Iron

**D**ATA on the linear thermal expansion of high-silicon cast iron containing approximately 14% of silicon, with 3% of molybdenum and without appreciable molybdenum, at various temperatures between 20° and 700° C. are given. Both high-silicon cast irons were found to have slightly higher coefficients of expansion than electrolytic iron for temperature ranges between 20° and 300° C., and appreciably higher coefficients for higher temperature ranges. No indication of growth similar to that of ordinary cast iron was observed on heating the high-silicon cast iron to 700° C.

P. Hidnert and G. Dickson: *Journal of Research of the National Bureau of Standards*, April, 1944.

**THE British Aluminium Co. Ltd.,** announce the following vacancies on the Staff of their Research Laboratories: Senior Metallurgist to lead a group working on light alloys. Applicants should be aged 30-40, with first-class qualifications and experience in metallurgical research. Two Metallurgists or Metallurgical Chemists to take charge of sections in this group. Applicants, aged 25-35, should be fully qualified and have research experience. The fullest particulars should accompany all applications. Further vacancies for metallurgists and physical chemists on the senior staff will be announced later, but particulars can be obtained now on application by those interested in post-war employment. Address to the General Manager, British Aluminium Co. Ltd., Salisbury House, London Wall, London, E.C.2.

The following Laboratory Fittings are required:

Wall Bench about 18 ft. long with sinks and fittings.

Fume Cupboard, 3 ft. by 2 ft. 3 in.

Laboratory Table, with drawers, about 7 ft. by 3 ft. 3 ins.

Apparatus Cupboard, with glass doors.

The Walterisation Co. Ltd., Purley Way, Croydon

**M**ETALLURGICAL WRITER REQUIRED for production of comprehensive catalogue covering products of large Steel Works manufacturing special steels, including Tool Steel, Alloy Steel, Forgings, Castings, etc. Would require whole-time service for considerable period with prospect of continuing employment on publicity. Applicants, who must have good metallurgical experience on steel and its applications should state qualifications and quote any technical or advertising literature for which they have been responsible, age, present employment, and a general indication of salary, to Box No. 140.

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